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General Geology Report 72

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FOSSIL PLANTS FROM THE ANTHRACITE COAL FIELDS OF EASTERN PENNSYLVANIA

John Oleksyshyn

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General Geology Report 72

FOSSIL PLANTS FROM THE ANTHRACITE COAL FIELDS OF EASTERN PENNSYLVANIA

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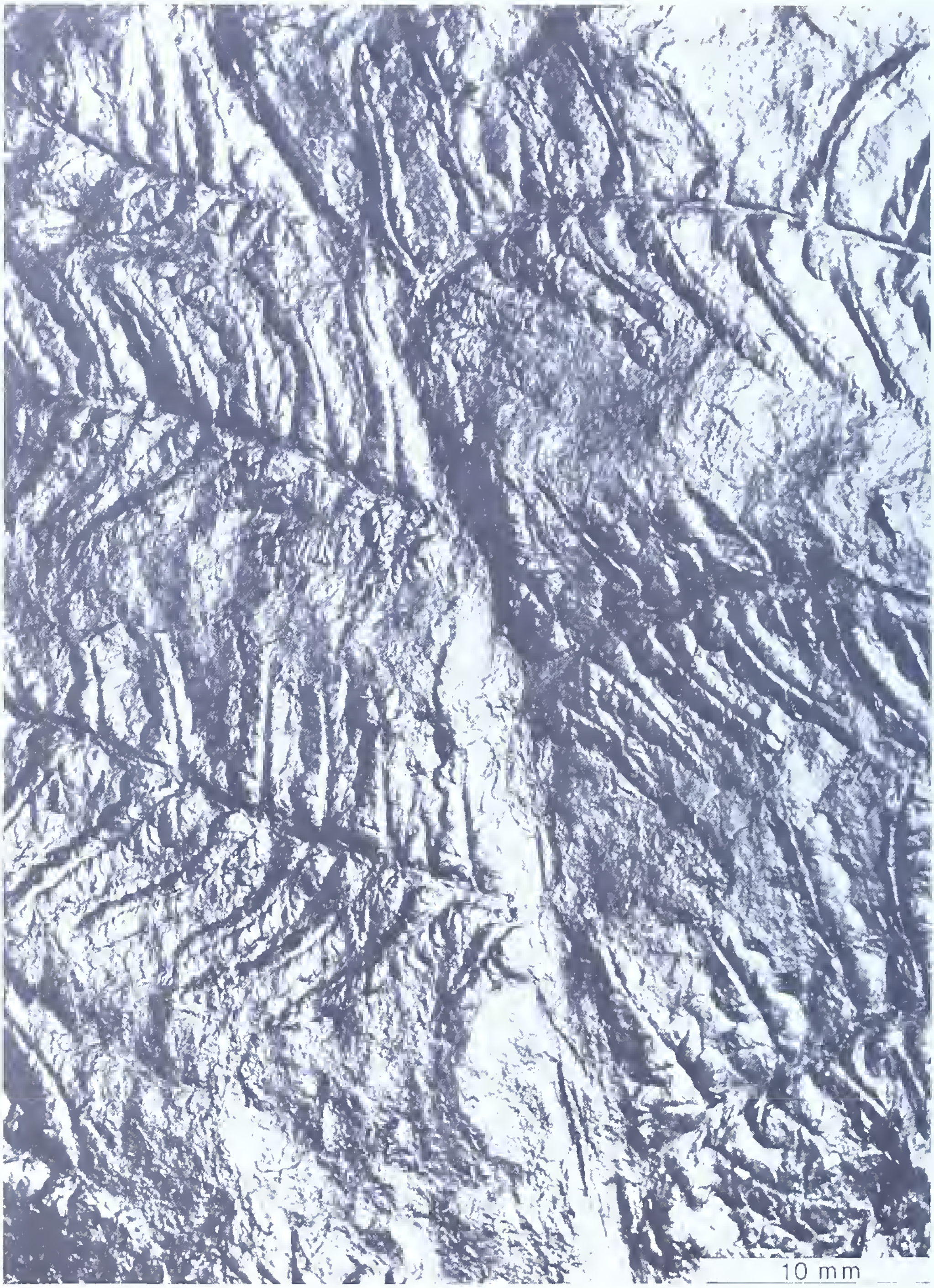

Pecopteris plumosa (Artis) forma *dentata* Brongniart.

FOSSIL PLANTS FROM THE ANTHRACITE COAL FIELDS OF EASTERN PENNSYLVANIA

by

John Oleksyshyn[1]

ABSTRACT

The fossil plants described and illustrated in this paper were collected in the shale and siltstone below the Buck Mountain (No. 5) coal bed in the lower portion of the Llewellyn Formation (the middle and upper parts of the Alleghenian; the lower portion of the Upper Pennsylvanian) near the borough of St. Clair in the Southern Anthracite coal basin of Pennsylvania, and in the shale and siltstone above the Baltimore coal bed in a slightly higher position in the Llewellyn Formation (near the top of the Alleghenian; the lower portion of the Upper Pennsylvanian) near the village of Wanamie in the Northern Anthracite coal basin of Pennsylvania. Thirty-eight species of Upper Carboniferous fossil plants were collected in the shale and siltstone below the Buck Mountain (No. 5) coal bed near St. Clair: two of them belong to the family Lepidodendraceae; two to Sigillariaceae; four are sterile foliage shoots of calamitean affinity, two of *Asterophyllites* and two of *Annularia* type; six belong to the family Sphenophyllaceae; three to Sphenopteridaceae; one to Eusphenopteridaceae; three to Mariopteridaceae; four to Pecopteridaceae; six to Alethopteridaceae; and seven to Neuropteridaceae. Forty-four species of Upper Carboniferous fossil plants were collected in the shale and siltstone above the Baltimore coal bed near Wanamie: five of them belong to the family Lepidodendraceae; eight to Sigillariaceae; three to Calamitaceae; two to Eusphenopteridaceae; one to Mariopteridaceae; twelve to Pecopteridaceae; one to Dicksoni(i)aceae; two to Alethopteridaceae; six to Neuropteridaceae; and four to Cordaitaceae. The geologic age of the described fossil plants is Westphalian D; they are assigned to the 10th floral zone of Read and Mamay (1964).

INTRODUCTION

The first systematic study of Carboniferous fossil plants in the United States was done by Leo Lesquereux in the second half of the nineteenth century. His first collections were made in the vicinity of Pottsville in the Southern Anthracite coal basin of Pennsylvania and later in the vicinity of Wilkes-Barre and Scranton in the Northern Anthracite coal basin of Pennsylvania. Lesquereux also collected fossil plants in the bituminous coal region of western Pennsylvania, Ohio, and Illinois. Descriptions and illustrations of fossil plants collected by him were published in many reports.

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Collections of Lesquereux, and those made by other collectors and examined by him, were originally preserved in different institutions. Some specimens were apparently destroyed or lost during transfers to the repositories at the paleobotanical collections of Harvard University, the National Museum in Washington, D.C., the Illinois State Natural History Museum in Springfield, and the William Penn Memorial Museum in Harrisburg, Pennsylvania.

Notable contributions to our knowledge of Carboniferous floras and interregional stratigraphic correlations, especially floras of the Pottsville Group and their correlation with contemporaneous floras of western Europe, were made by David White (1899). Read and Mamay (1964) also tried to establish a stratigraphic succession of Carboniferous floras in the United States.

Monographs dealing with some groups of fossil plants published in the last few decades suggest the necessity of revision of old descriptions and the need to collect additional specimens. Unfortunately many of the old collections came from mines and strip mines that have been abandoned for a long time and are now inaccessible.

OUTLINE OF GEOLOGY OF THE ANTHRACITE COAL BASINS OF PENNSYLVANIA

Fossil plants described in this paper were collected in the shale and siltstone below the Buck Mountain (No. 5) coal bed in the lower part of the Llewellyn Formation (Figure 1) and in the shale and siltstone above the Baltimore coal bed in a slightly higher position in the Llewellyn Formation (Figure 2). The Llewellyn forms part of the Upper Carboniferous (Pennsylvanian) strata of the anthracite coal basins of eastern Pennsylvania.

There are two distinct anthracite coal regions (Figure 3). One, the Northern Anthracite field in the vicinity of Wilkes-Barre and Scranton, is a long, narrow syncline extending in a southwest-northeast direction. The other, the Southern Anthracite region, is more complex, consisting of a few synclines of various sizes, more or less closely interconnected and forming three separate fields: the Southern Anthracite field in the vicinity of Tower City, Tremont, Pottsville, and Tamaqua; the Western Middle Anthracite field in the vicinity of Mt. Carmel and Mahanoy City; and the Eastern Middle Anthracite field in the vicinity of Hazleton and Freeland.

The strata that crop out around the rim of each of the above-mentioned anthracite coal basins represent mainly terrestrial deposits of Late Devonian and Early Carboniferous (Mississippian) age (Figure 3). The oldest of these is the Mississippian-Devonian Spechty Kopf Formation, which consists of

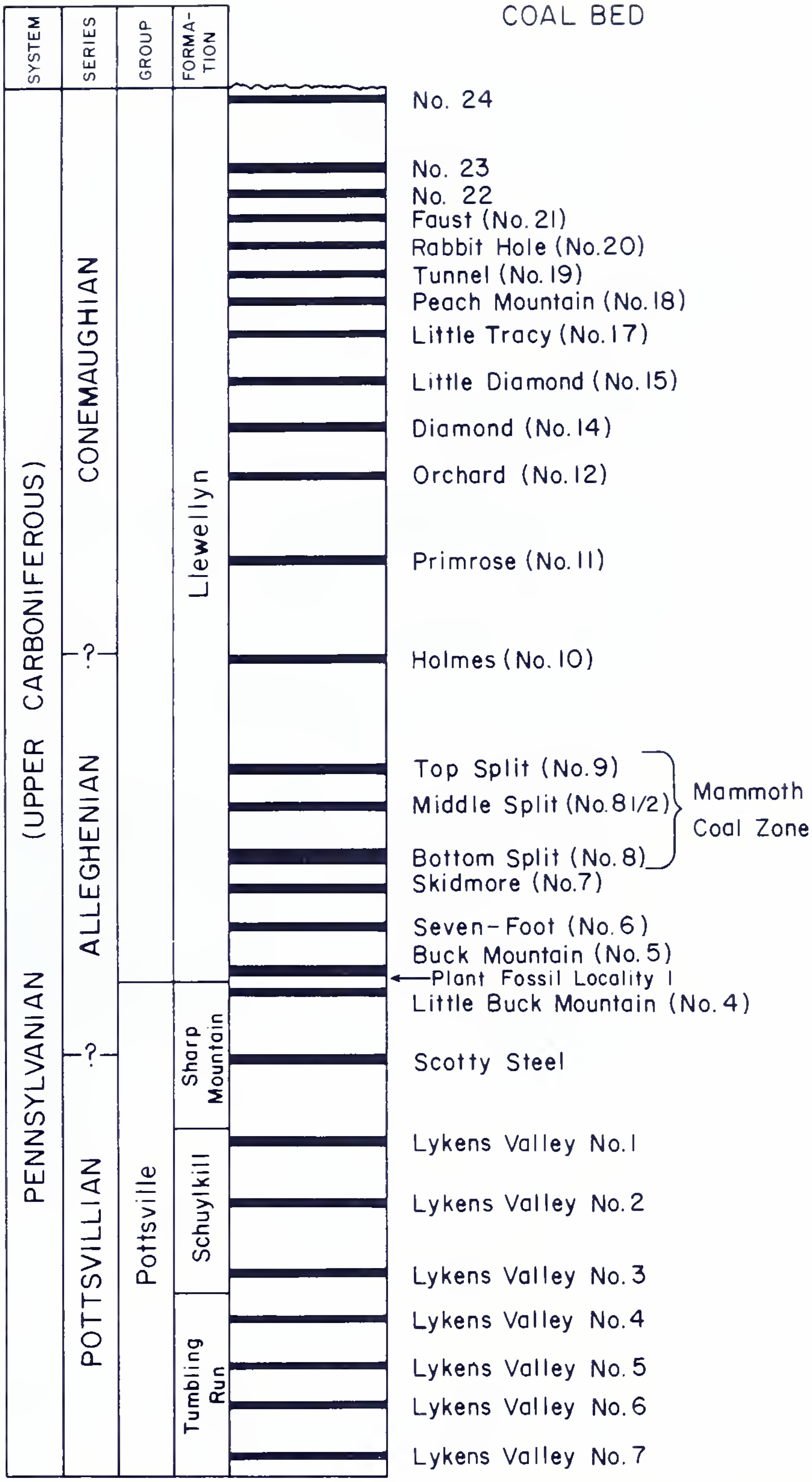

Figure 1. Generalized stratigraphic section of Upper Carboniferous strata in the vicinity of St. Clair, near Pottsville, Pennsylvania, in the Southern Anthracite coal field.

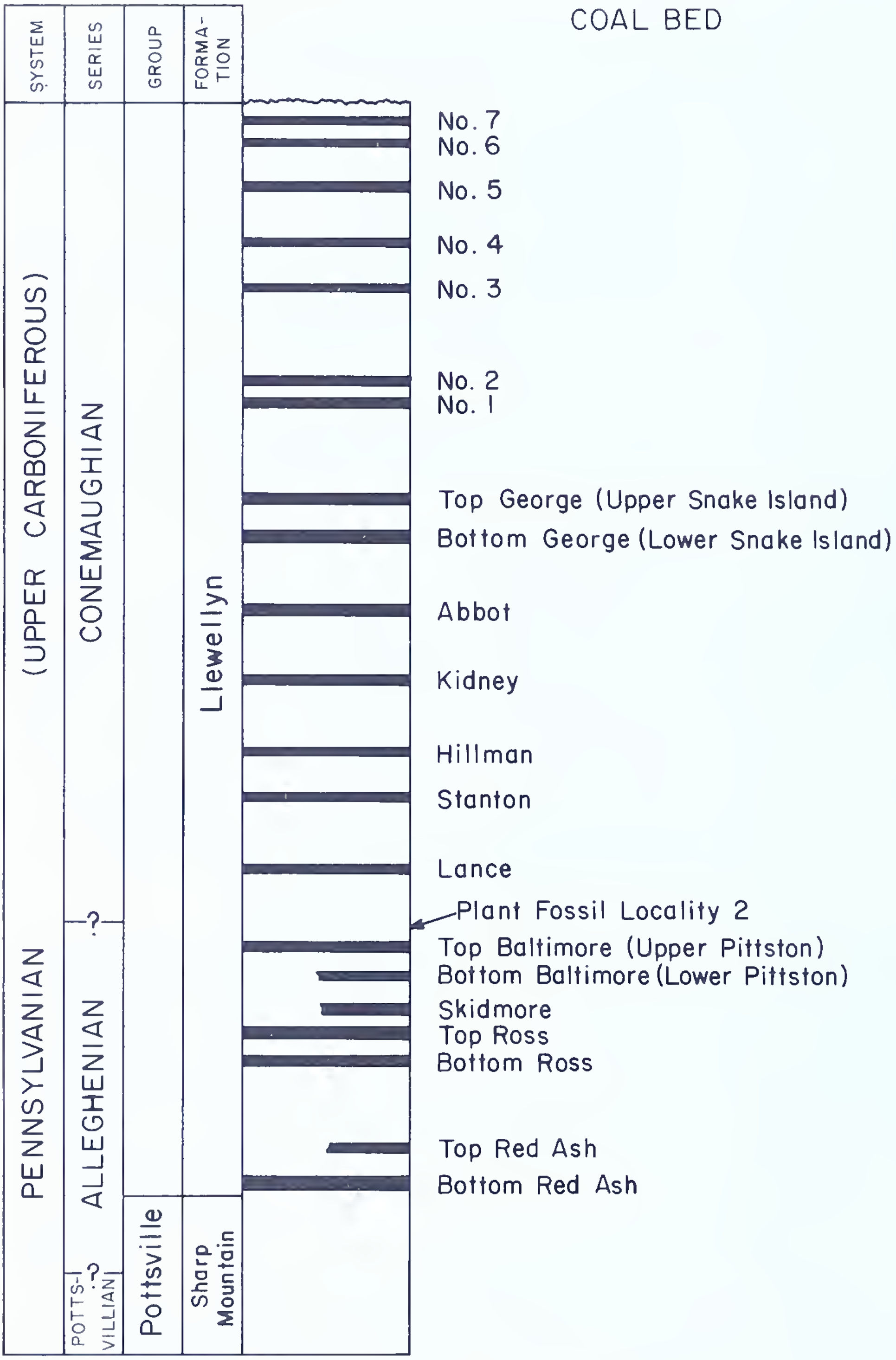

Figure 2. Generalized stratigraphic section of Upper Carboniferous strata in the vicinity of Wanamie, near Wilkes-Barre, Pennsylvania, in the Northern Anthracite coal field.

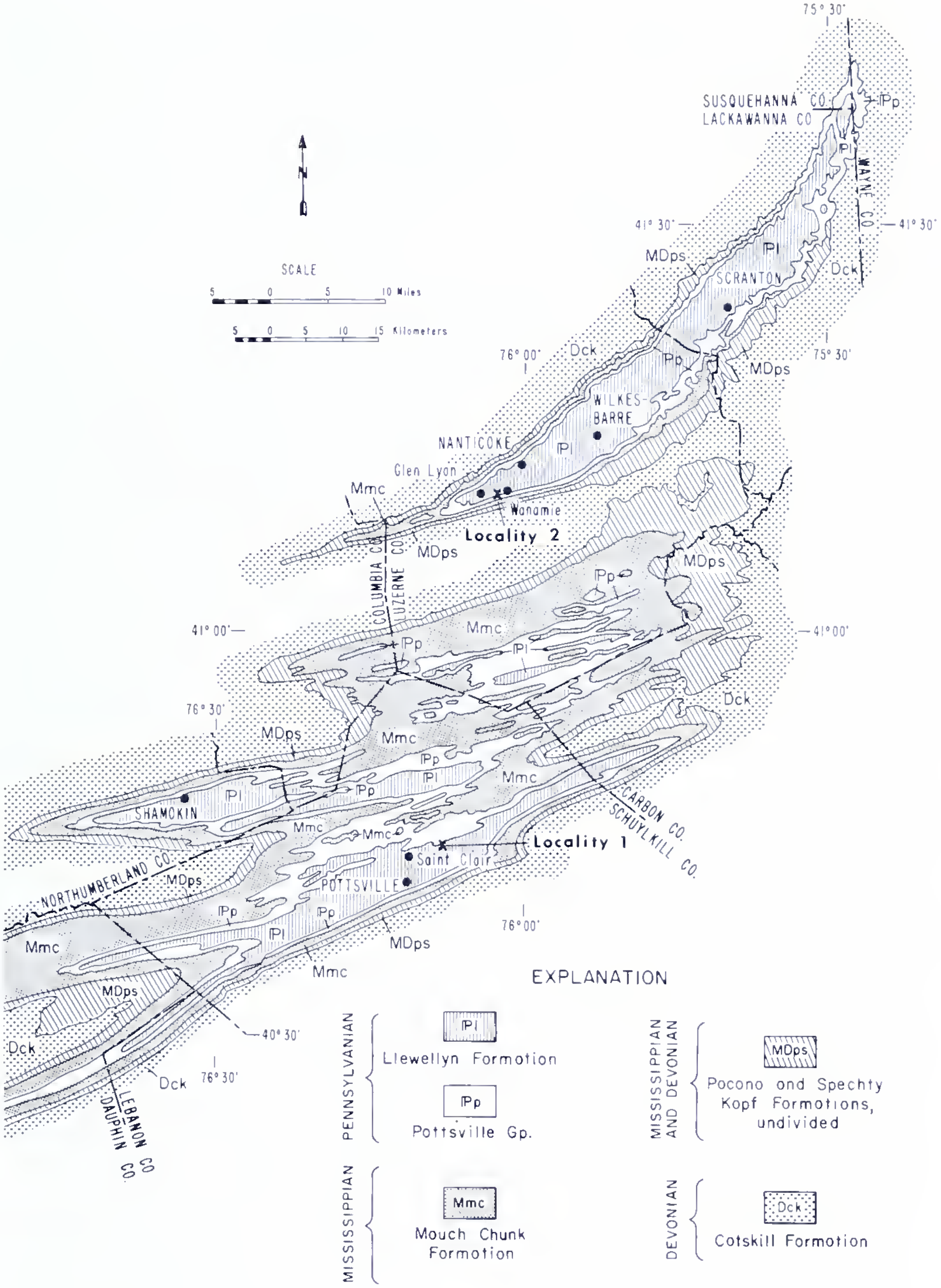

Figure 3. Geologic map of the Anthracite coal region of eastern Pennsylvania (simplified from Berg and others, 1980). Faulting is not shown due to the small scale of the map.

sandstone, siltstone, and local pebbly mudstone and laminite. Overlying the Spechty Kopf is the Pocono Formation, made up of conglomerate grading upward into sandstone and some shale; thin coal beds are occasionally present. In most places the Pocono is overlain by brown and greenish-gray sandstone and red shale of the Mauch Chunk Formation.

Pennsylvanian strata below the Buck Mountain coal bed are included in the Pottsville Group of Early and mainly Middle Pennsylvanian age. This group includes, in ascending order, the Tumbling Run, Schuylkill, and Sharp Mountain Formations, composed predominantly of cobble and pebble conglomerate, conglomeratic sandstone, and lesser amounts of siltstone, shale, and anthracite. In the upper part of the section, above the Pottsville Group, are gray and brown beds of conglomeratic sandstone, quartzose subgraywacke, siltstone, and a small amount of conglomerate, shale, and anthracite. Except for the anthracite beds these rocks do not contain widespread lithologic units that permit them to be stratigraphically subdivided; therefore, for all these ''post-Pottsville rocks'' the name Llewellyn Formation was proposed by Wood and others (1962). A type section of this formation cannot be designated because exposures are discontinuous and the strata are structurally complex. The type area, in the vicinity of the borough of Llewellyn in the Minersville synclinorium, is complexly folded, faulted, and overthrusted.

The contact between the Llewellyn Formation and the underlying strata of the Sharp Mountain Formation is placed at the base of the shale or underclay that underlies the Buck Mountain (No. 5) coal bed. In places where the shale or clay is absent, the contact is placed at the base of the abovementioned coal bed. The upper boundary of the Llewellyn Formation is in most places the present erosional surface. In a few places the formation is covered unconformably by Pleistocene and alluvial deposits or by debris from strip pits and coal mines.

The original thickness of the Llewellyn Formation cannot be determined accurately, because its upper portion has been eroded and because of structural complications. Its maximum thickness is estimated at about 1,067 m (3,500 ft) near Llewellyn in the Minersville quadrangle (Wood and others, 1962, p. C42). Lateral variations in the thickness and lithology are locally striking, but the continuity of some units over large areas, especially the anthracite beds, is evident in the lower and middle portion of this formation. The upper part of the formation is usually poorly exposed; therefore, the extent of its variation in thickness and lithology has not been determined.

Lithologic and sedimentary features of the Llewellyn Formation indicate that it was derived from quartz veins in schist of the Wissahickon Formation, carried onto the floodplain by sluggishly flowing streams from eastern Pennsylvania. Some uplift of this region is indicated by the conglomerates of the Pottsville Group. The uplift took place during late Middle Pennsylvanian time. The scattered conglomerate, conglomeratic sandstone, and coarse sandstone in the Llewellyn Formation indicate that the region to the southeast of the depositional area was also uplifted intermittently during Late Pennsylvanian time.

The structural features of rocks in the Anthracite region of eastern Pennsylvania, which lies in the Valley and Ridge province, are consequences of the Alleghanian orogeny, which took place during the Late Paleozoic.

AGE OF FOSSIL PLANTS

Previous studies (e.g., Darrah, 1970) indicate that the Llewellyn Formation in the Southern Anthracite field is probably equivalent to the middle and upper parts of the Allegheny Group, the Conemaugh Group, and the lowermost part of the Monongahela Group of the bituminous coal fields in western Pennsylvania,[1] and that the Llewellyn in the Northern Anthracite field is equivalent to the middle and upper parts of the Allegheny Group and the lower and middle parts of the Conemaugh Group. The Allegheny, Conemaugh, and Monongahela Groups are equivalent to the Westphalian C and D and Stephanian A, B, and C strata of Europe. The Allegheny is also equivalent to the Pictou Group of New Brunswick and Nova Scotia, Canada. Figure 4 is a correlation chart showing the relationship among Pennsylvanian and Permian time-stratigraphic, rock-stratigraphic, and geologic-time units in the Anthracite region of Pennsylvania, the Appalachian bituminous fields, the Maritime Provinces of Canada, and western Europe.

The fossil plants described in this report were collected from the portion of the Llewellyn Formation that is equivalent to the middle and upper parts of the Allegheny Group. The age of the plants is Westphalian D.

COLLECTING LOCALITIES

The collecting locality below the Buck Mountain (No. 5) coal bed is located on the west bank of the upper part of Silver Creek, about 2.7 km (1.5 mi) east-northeast of St. Clair, Schuylkill County, in the Pottsville quadrangle, on the east side of the road from St. Clair to Mahanoy City (Figure 5). Fossil plants at this locality are replaced by pyrophyllite, a white, greasy-textured, layered silicate (Myer and others, 1977). Because this mineralogical replacement has resulted in exceptional preservation of plant structures, the St. Clair locality is perhaps the best known plant-fossil locality in Pennsylvania. *Permission to enter the site must be obtained from Reading Anthracite Coal Company.*

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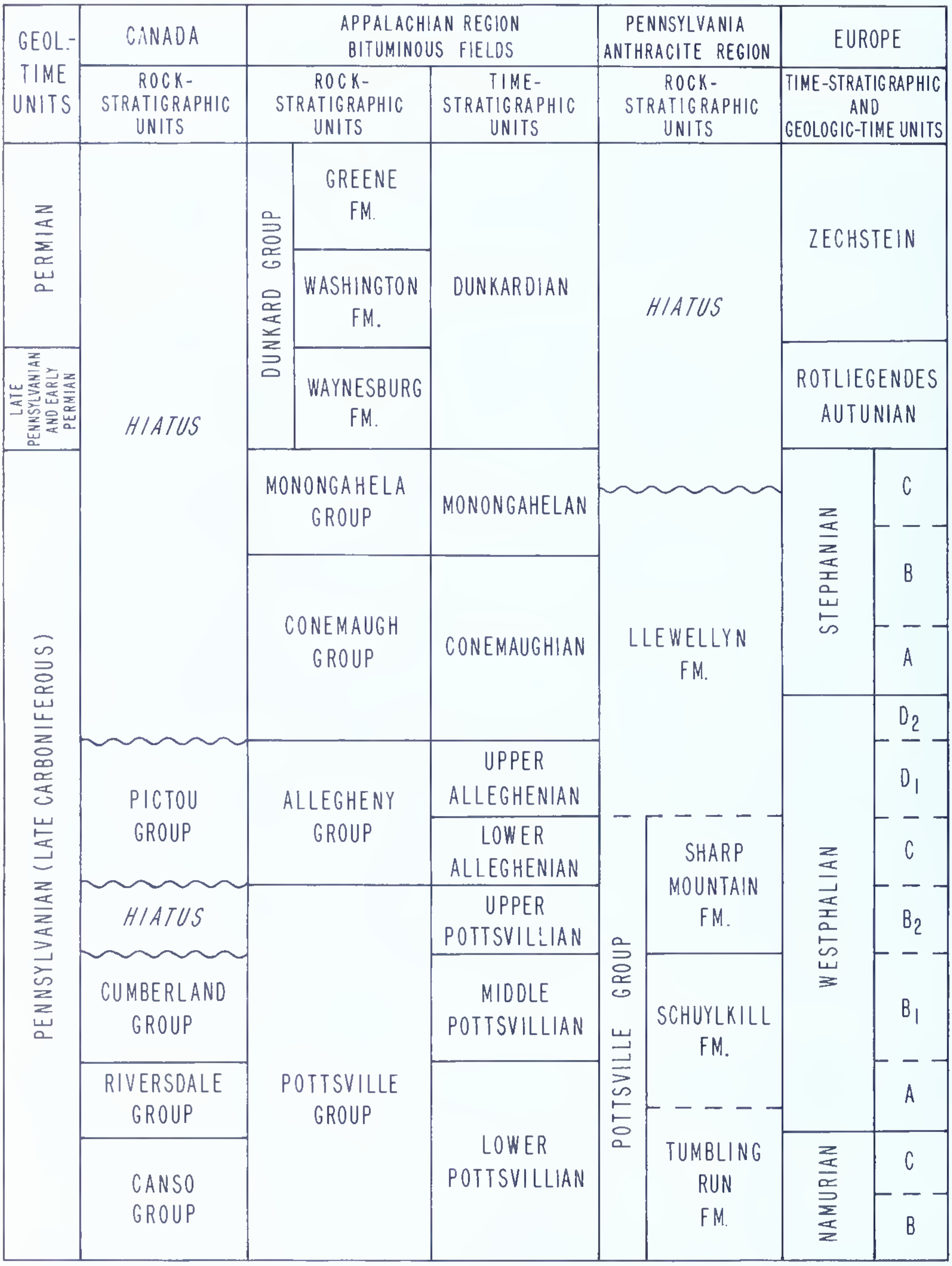
[1] Some authors (e.g., Wood and others, 1962) believe that the top of the Llewellyn Formation correlates with the middle part of the Conemaugh Group. This problem may be clarified only by further studies of fossil plants from the Llewellyn Formation.



GEOL.-TIME UNITS	CANADA	APPALACHIAN REGION BITUMINOUS FIELDS			PENNSYLVANIA ANTHRACITE REGION		EUROPE	
	ROCK-STRATIGRAPHIC UNITS	ROCK-STRATIGRAPHIC UNITS		TIME-STRATIGRAPHIC UNITS	ROCK-STRATIGRAPHIC UNITS		TIME-STRATIGRAPHIC AND GEOLOGIC-TIME UNITS	
PERMIAN	*HIATUS*	DUNKARD GROUP	GREENE FM.	DUNKARDIAN	*HIATUS*		ZECHSTEIN	
			WASHINGTON FM.					
LATE PENNSYLVANIAN AND EARLY PERMIAN			WAYNESBURG FM.				ROTLIEGENDES AUTUNIAN	
PENNSYLVANIAN (LATE CARBONIFEROUS)		MONONGAHELA GROUP		MONONGAHELAN			STEPHANIAN	C
					LLEWELLYN FM.			
								B
		CONEMAUGH GROUP		CONEMAUGHIAN				
								A
							WESTPHALIAN	D_2
	PICTOU GROUP	ALLEGHENY GROUP		UPPER ALLEGHENIAN				D_1
				LOWER ALLEGHENIAN	POTTSVILLE GROUP	SHARP MOUNTAIN FM.		C
	HIATUS	POTTSVILLE GROUP		UPPER POTTSVILLIAN				B_2
	CUMBERLAND GROUP			MIDDLE POTTSVILLIAN		SCHUYLKILL FM.		B_1
	RIVERSDALE GROUP			LOWER POTTSVILLIAN				A
						TUMBLING RUN FM.		
							NAMURIAN	C
	CANSO GROUP							
								B

Figure 4. Correlation chart of Pennsylvanian and Permian strata in the Anthracite region of Pennsylvania, the bituminous fields of the Appalachian region, the Maritime Provinces of Canada, and western Europe.

The collecting locality above the Baltimore coal bed is located about 1.5 km (0.9 mi) west of Wanamie, Luzerne County, in the Nanticoke quadrangle, on the south side of the road from Wanamie to Glen Lyon (Figure 6).

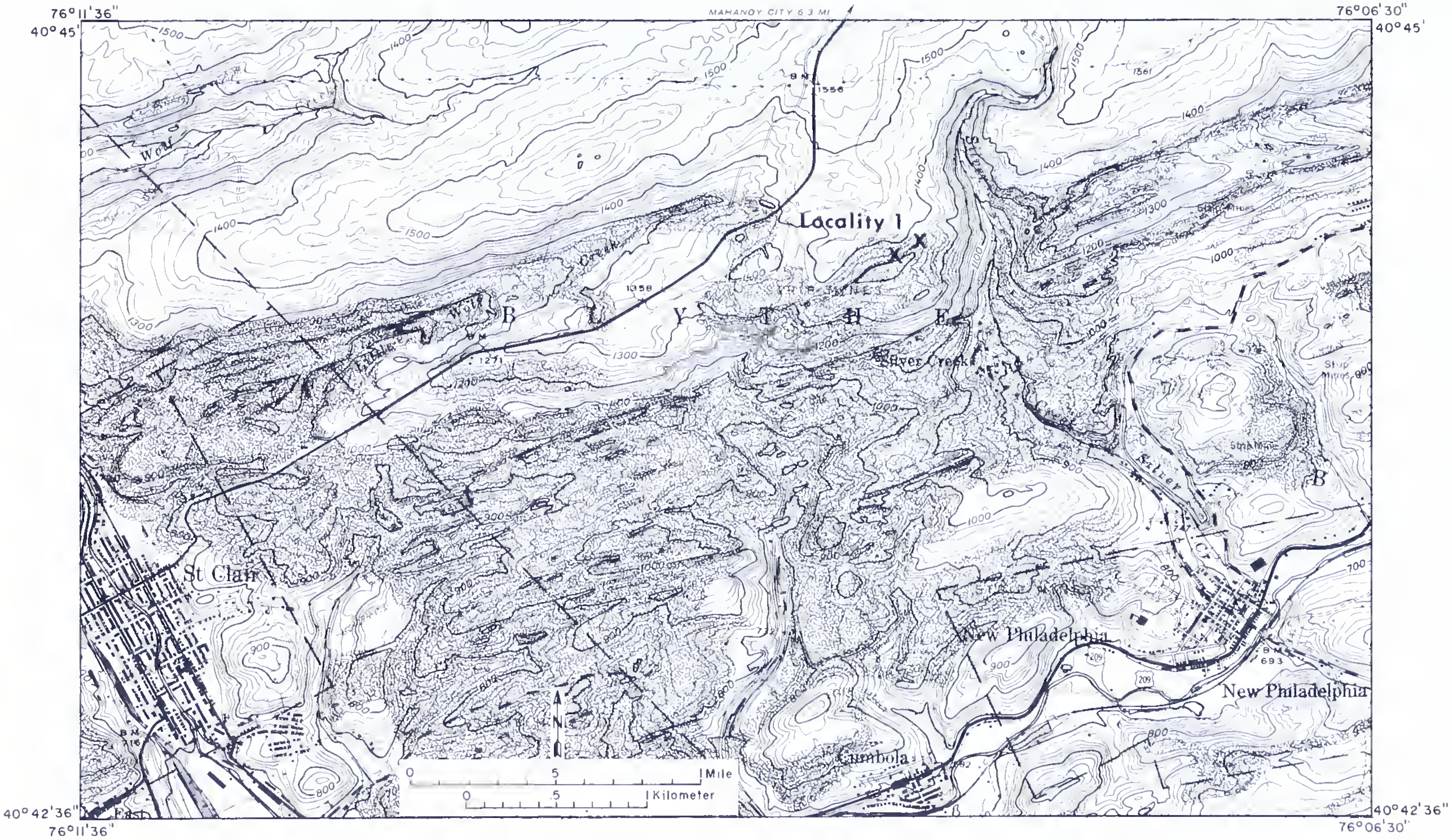


Figure 5. Collection locality in the Buck Mountain (No. 5) coal bed in the vicinity of St. Clair, Pennsylvania.

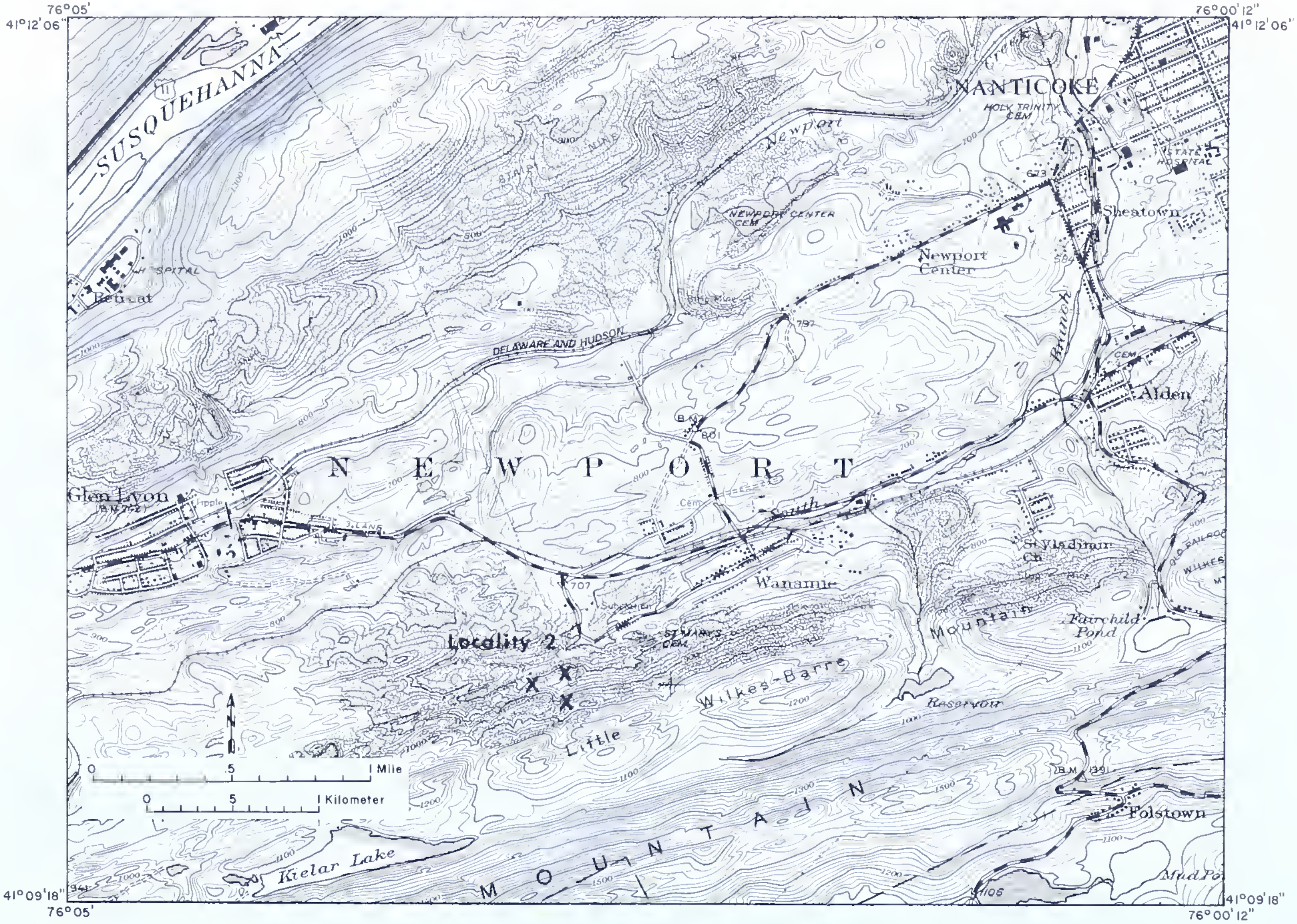


Figure 6. Collection locality in the Baltimore coal bed in the vicinity of Wanamie, Pennsylvania.

DEPOSITORY OF SPECIMENS

The fossil plants described and illustrated in this paper have been deposited in the William Penn Memorial Museum (WPMM) in Harrisburg, Pennsylvania.

ACKNOWLEDGEMENTS

I am very grateful to Dr. William C. Darrah, Professor of Biology Emeritus, Gettysburg College, Gettysburg, Pennsylvania, who examined my collection of fossil plants, critically reviewed my manuscript, and made several helpful comments and suggestions, and to Dr. Paul C. Lyons, Geologist, U.S. Geological Survey, Branch of Coal Resources, Reston, Virginia, for his critical review of the manuscript and many suggestions during its preparation. I am indebted to Dr. Jon D. Inners, Geologist, Pennsylvania Geological Survey, who critically read the manuscript and prepared most of the glossary. Also I am very thankful to Dr. Hermann W. Pfefferkorn, Professor of Geology, University of Pennsylvania, Philadelphia, Pennsylvania, for many valuable suggestions during the preparation of the manuscript.

I thank Hon. James J. Curran, President of Reading Anthracite Coal Company, Pottsville, Pennsylvania; Mr. Charles Martin, President of Cassel Coal Company, Minersville, Pennsylvania; and Mr. Charles G. Zink, Vice President of Jeddo-Highland Coal Company, Pittston, Pennsylvania, for giving me permission to enter the property of their companies to search for plant fossils and conduct other geological studies.

DESCRIPTION OF FOSSIL PLANTS

KINGDOM PLANTAE
Phylum TRACHEOPHYTA
Subphylum LYCOPODIOPHYTA
Class LYCOPSIDA
Order LEPIDODENDRALES
Family LEPIDODENDRACEAE
Genus *Lepidodendron* Sternberg, 1820
Lepidodendron aculeatum Sternberg, 1820b
(Figure 7A)

Lepidodendron aculeatum Sternberg, 1820a, p. 21, 15; pl. 6, fig. 2; pl. 8, figs. 113, 6; fasc. 4, p. X; 1820b, p. 20, 23, pl. 6, fig. 2; pl. 8, figs. 1B, a, b.

Lepidodendron aculeatum Sternberg. Lesquereux, 1879, pl. 64, fig. 1; 1880, p. 371.
Lepidodendron aculeatum Sternberg. Gothan and Remy, 1957, p. 65, fig. 55; chart 5.
Lepidodendron aculeatum Sternberg. Crookall, 1964, p. 233, pl. 60, fig. 6; text-fig. 77A. (Contains a more complete synonymy.)

DESCRIPTION: The specimen represents only a few spindle-shaped leaf cushions, about three times as long as they are broad, having the maximum width above the middle. The upper and lower ends of each leaf cushion are acuminate and inflected in opposite directions; the lateral angles are broadly rounded. The rhomboidal-ovate leaf scar situated slightly above the middle of each leaf cushion is fairly large in relation to the size of the cushions and has at its base the usual three round folial prints; the upper and lower portion of each cushion bears a ridge-like structure, the keel, which in the lower portion is crossed by distinct transverse marks.

REMARKS: *Lepidodendron aculeatum* has some similarity to *L. obovatum* Sternberg and *L. dichotomum* Sternberg. The main differences between these three species are as follows: (1) the outline of the leaf cushion in the first species is spindle-shaped, whereas in the second and third species it is rhomboidal; (2) the leaf cushions in the first and third species are symmetrical, whereas in the second species they are asymmetrical; (3) the leaf cushion in the first species is about three times as long as it is broad, in the second species is slightly longer than broad, and in the third species is about as long as broad; and (4) the base and the apex of the leaf cushions in the first species are distinctly inflected in opposite directions, in the second species are slightly inflected, and in the third species are not inflected. In addition, the keel above the leaf scar is distinct in *L. aculeatum*, is relatively small in *L. obovatum* , and is practically absent in *L. dichotomum.* The keel below the leaf scar in the first and second species is distinct, but in the third species is not distinct. The lateral angles of the leaf cushions in the first species are broadly rounded, in the second species are more rounded, and in the third species are sharp. There are also some differences in the size of, position of, and relation of length to width in the leaf scars between these three species.

DISTRIBUTION: *Lepidodendron aculeatum* is found in strata ranging from middle Pottsvillian to uppermost Alleghenian (Westphalian B, C, and D) and their equivalents in the Appalachian and central regions of the United States. It is also known from the Cumberland Group (Westphalian B_1) of Nova Scotia, Canada. In Europe, this species is known from the Namurian C and the entire Westphalian, but it is most common in the Westphalian B and lower C.

SPECIMEN: WPMM F482.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Lepidodendron lanceolatum Lesquereux, 1880
(Figure 7B)

Lepidodendron lanceolatum Lesquereux, 1879, p. 11, pl. 63, figs. 3-5, 5a; 1880, p. 369.

Lepidodendron lanceolatum Lesquereux. White, 1899, p. 192, pl. 53, fig. 2.

Lepidodendron lycopodioides Sternberg. Bell, 1938, p. 93, pl. 96, figs. 2, 3; pl. 97, figs. 1-3.

Lepidodendron lycopodioides Sternberg. Gothan and Remy, 1957, p. 67, 69, fig. 57; chart 5.

Lepidodendron lanceolatum Lesquereux sensu Noé. Crookall, 1964, p. 257, pl. 51, fig. 3. (Contains a more complete synonymy.)

Lepidodendron pictoense Dawson. Bell, 1962, p. 52, pl. 46, pl. 49, figs. 1, 3; pl. 50, figs. 1-3.

DESCRIPTION: The specimens represent a young stem and a few leafy shoots. Leaf cushions are rhomboidal and have rounded lateral angles and acute, straight, or slightly curved ends. The cushions are about 7 mm long and 4 mm wide and have a low keel, commonly crossed by short transverse wrinkles, below the leaf scar; there is no keel above the leaf scar. Leaf scars are rhomboidal and situated in the upper quarter of the cushions; they are large, about half the width of the leaf cushions. Lateral margins of the cushions are continuous downward and give rise to two short, descending, delicate ridges. The leafy shoots branch at acute angles. The lanceolate, uninerved leaves are 10 to 15 mm long and 1.5 to 2 mm broad near the base, depending upon the size of the stem, and are slightly S-shaped close to the strongly ascending base, which subsequently ascends at about 45 degrees. The leaf margin is fairly straight or, more generally, slightly curved in the upper half to the acuminate tip.

REMARKS: *Lepidodendron lanceolatum* is very similar to *L. ophiurus* Brongniart. The main differences between these two species are the presence of a strong keel above the leaf scar and more angular lateral margins of the cushions in *L. ophiurus*; in *L. lanceolatum* the upper keel is not evident. *Lepidodendron lanceolatum* is synonymous with *L. lycopodioides* Zeiller (non Sternberg) and *L. pictoense* Dawson (Bell, 1962, p. 40-41).

DISTRIBUTION: *Lepidodendron lanceolatum* is known from Pottsvillian and Alleghenian (Westphalian A through D) strata in the Appalachian region, from contemporaneous strata in the central regions, and from the Rhode Island Formation (Westphalian C and D) of the Narragansett basin of New England. It is also known from the Riversdale Group (Westphalian

A) and Morien (Pictou) Group (Westphalian C and D) of the Sydney coal field in Nova Scotia, Canada. In Europe, this species is known from the Westphalian A, B, C, and lower D.

SPECIMEN: WPMM F483.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Lepidodendron cf. *rimosum* Sternberg, 1820b
(Figure 7C)

Lepidodendron rimosum Sternberg, 1820b, p. 21, 23, pl. 10, fig. 1.
Lepidodendron rimosum Sternberg. Lesquereux, 1879, pl. 64, fig. 11; 1880, v. 2, p. 392.
Lepidodendron rimosum Sternberg. Bell, 1944, p. 90, pl. 46, fig. 2.
Lepidodendron rimosum Sternberg. Crookall, 1964, p. 248, pl. 70, figs. 1-6; text-fig. 81. (Contains a more complete synonymy.)

DESCRIPTION: The specimens represent the impressions of the cortex of the stem. Leaf cushions are fusiform to rhomboidal, and slightly convex, averaging 48 mm long and 9 mm broad in the widest part of the cushions. The longitudinal keel is prominent on the top of the cushions, about 0.8 mm wide and bent near the leaf scar. Some keels bear distinct transverse notches. Both sides of the cushions and the surface between the cushions are ornamented by fairly coarse reticulation and a few scattered, fine, discontinuous lines extending more or less parallel to the margin of the cushions. All of these lines, which are irregular in interval and uneven in direction, indicate that the bark had sharp, nearly longitudinal ridges.

The leaf scars, situated just above the middle of the cushions, occupy from one third to nearly the entire cushion width. The leaf scars are rhomboidal with narrowly rounded upper and lower angles and less acute lateral angles. A short arched line, which arises from each lateral angle, descends and joins the margin of the cushion at about the middle point. On some cushions an arched line surmounts the leaf scar. Three subcircular bundle scars are situated close together below the middle of the leaf scar; the oval scars—the parichnos and the punctiform scar of the ligule-pit—are evident on some cushions above the leaf scar.

REMARKS: *Lepidodendron rimosum* has some similarities to *L. dissitum* Sauveur and to *L. dawsoni* Bell. In some specimens the differences between these "species" are so small that it is difficult to separate them. Bell (1938, p. 95), in his remarks on *L. dawsoni*, stated that the older stems of this species strongly resemble *L. rimosum*.

DISTRIBUTION: *Lepidodendron rimosum* is known from Upper Pottsvillian, Alleghenian, and lower Conemaughian (Westphalian B, C, and D) strata in the central and Appalachian regions of the United States, and from the Morien (Pictou) Group (Westphalian C and D) of Nova Scotia, Canada. In Europe, this species is common in the Westphalian A, fairly frequent in the Westphalian B, and very rare in the Westphalian C and D.

SPECIMEN: WPMM F666.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus *Lepidostrobophyllum* Hirmer, 1927

Lepidostrobophyllum lanceolatum (Lindley and Hutton) Hirmer, 1927

(Figure 7D, E)

Lepidophyllum lanceolatum Lindley and Hutton, 1831, p. 28, pl. 7, figs. 3, 4.

Lepidostrobus lanceolatus Brongniart. Lesquereux, 1879, pl. 69, fig. 38; 1880, p. 436.

Lepidostrobophyllum lanceolatum (Lindley and Hutton). Hirmer, 1927, p. 231.

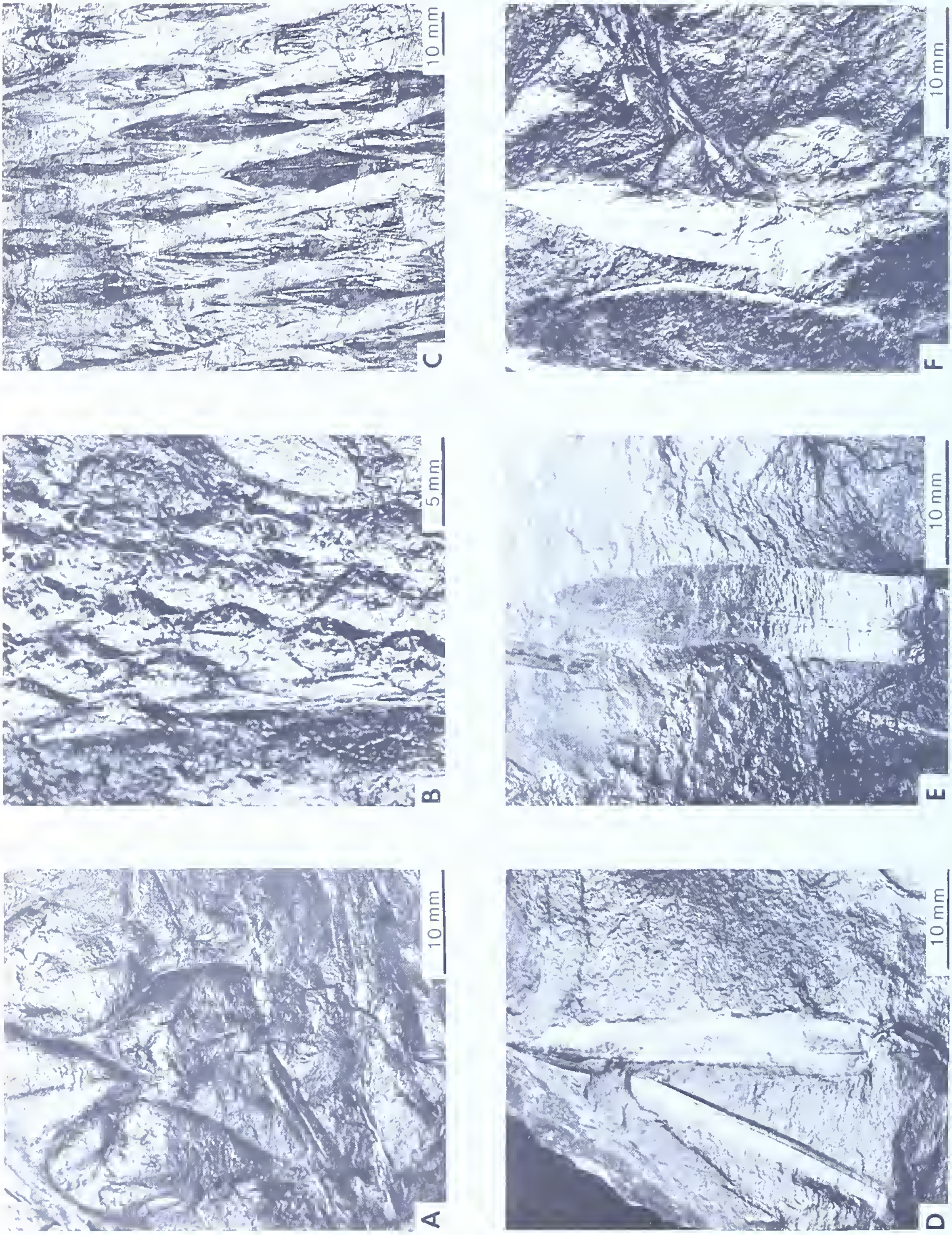
Lepidostrobophyllum lanceolatum (Lindley and Hutton). Bell, 1938, p. 97, pl. 98, figs. 7-11.

Lepidostrobus lanceolatus Lindley and Hutton. Crookall, 1966, p. 503, pl. 99, figs. 4, 5. (Contains a more complete synonymy.)

DESCRIPTION: The specimens represent a few detached sporophylls with pedicels. The sporophylls are lanceolate, 28 to 35 mm long and 6 to 8 mm broad at their widest portion below the middle of the lamina; apices are acute. The central vein is prominent, about 0.75 mm broad near the base of the lamina, tapering gradually to the apex, and is marked by a faint medial furrow. The pedicel is wedge shaped, 6 to 8 mm long and about 5 mm broad in the upper portion near the base of the lamina.

REMARKS: The "generic" name *Lepidostrobophyllum* was introduced by Hirmer (1927, p. 231) to designate the detached sporophylls of *Lepidostrobus*, which includes the detached cones not only of *Lepidodendron* but also of *Lepidophlois* and *Bothrodendron*, generically indistinguishable when separated from the parent plants. Therefore, because it is often difficult to be sure whether it is a sporophyll from which the sporangium has become detached or a vegetative leaf, Crookall (1966, p. 503) used the name *Lepidostrobus*.

DISTRIBUTION: *Lepidostrobophyllum lanceolatum* is known from Pennsylvanian (Upper Carboniferous) strata in the central and Appalachian regions of the United States, and from the Riversdale Group (Westphalian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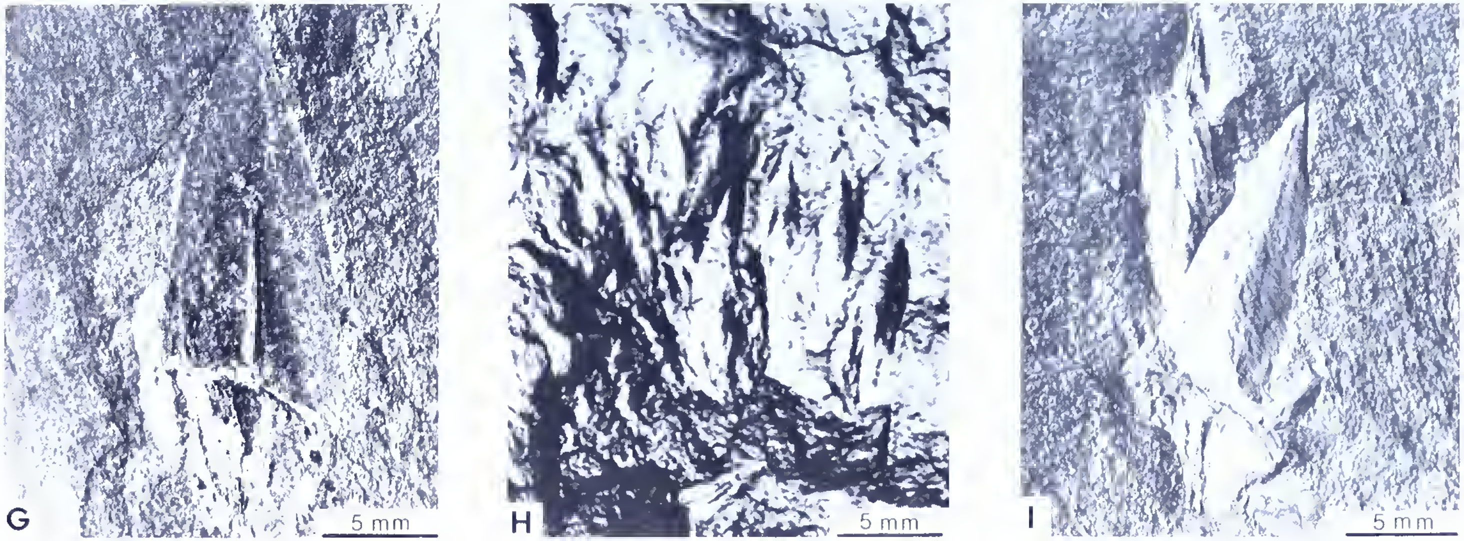


Figure 7. A. *Lepidodendron aculeatum* Sternberg [WPMM F482]; B. *Lepidodendron lanceolatum* Lesquereux [WPMM F483]; C. *Lepidodendron* cf. *rimosum* Sternberg [WPMM F666]; D, E. *Lepidostrobophyllum lanceolatum* (Lindley and Hutton) Hirmer [WPMM F719b]; F. *Lepidostrobophyllum lancifolium* (Lesquereux) [WPMM F488]; G. *Lepidostrobophyllum ovatifolium* (Lesquereux) [WPMM F667]; H, I. *Lepidostrobophyllum triangulare* (Zeiller) [WPMM F491].

A) and Morien (Pictou) Group (Westphalian C and D) in Nova Scotia, Canada. In Europe, this species is known from several horizons of Lower and Upper Carboniferous strata.

SPECIMEN: WPMM F719b.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Lepidostrobophyllum lancifolium (Lesquereux), 1870
(Figure 7F)

Lepidostrobus lancifolius Lesquereux, 1870, p. 442, pl. 31, figs. 7, 7b.
Lepidostrobus lancifolius Lesquereux, 1879, pl. 69, figs. 30, 30a; 1880, p. 436.
Lepidostrobus lancifolius Lesquereux. Crookall, 1966, p. 514, pl. 101, fig. 13; text-fig. 145J. (Contains a more complete synonymy.)

DESCRIPTION: The specimen represents a sporophyll composed of a triangular pedicel about 5 mm long and 6 mm wide along the attachment of a lanceolate lamina, 27 mm long and 6 mm wide (widest in the middle), having diverging auricles at the base; the central vein extends from the base of the lamina to nearly its acuminated apex.

REMARKS: *Lepidostrobophyllum lancifolium* has some similarity to *L. lanceolatum* (Lindley and Hutton) Hirmer, but the lamina of the former is slightly smaller, is narrower, and has diverging auricles at the base. This sporophyll also has some similarity to *L. hastatus* Lesquereux, but the pedicel is shorter and the lamina much longer and narrower than in the latter.

DISTRIBUTION: *Lepidostrobophyllum lancifolium* is known from Pennsylvanian (Upper Carboniferous) strata in the central and Appalachian regions of the United States. In Europe, it is known only from the Westphalian A of England.

SPECIMEN: WPMM F488.

LOCALITY: Wanamie, near Wilkes-Barre, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Lepidostrobophyllum ovatifolium (Lesquereux), 1870
(Figure 7G)

Lepidostrobus ovatifolius Lesquereux, 1870, p. 441, pl. 30, figs. 2, 2b.
Lepidostrobus ovatifolius Lesquereux, 1879, pl. 69, fig. 32; 1880, p. 438.
Lepidostrobophyllum moyseyi? (Arber). Bell, 1938, p. 97, pl. 98, fig. 6.

Lepidostrobus ovatifolius Lesquereux. Crookall, 1966, p. 507, pl. 101, fig. 7; text-fig. 145D. (Contains a more complete synonymy.)

DESCRIPTION: The figured specimen is a detached sporophyll having an ovate lanceolate lamina 21 mm long with a maximum breadth of 9 mm in the lowest third; the apex is acute. The single midrib, about 1 mm wide at the base, bordered by a shallow groove on either side, is clearly evident only on the lower portion of the lamina. The pedicel of the sporophyll is triangular, and is 9 mm long and about 8 mm wide at the junction with the blade.

REMARKS: *Lepidostrobophyllum ovatifolium* is very similar to *L. moyseyi?* (Arber). It is also closely allied to *L. lanceolatum* (Lindley and Hutton) Hirmer, differing only in that its lamina has a concave upper surface, and the greatest width is near the base of the lamina.

DISTRIBUTION: *Lepidostrobophyllum ovatifolium* is known from Pennsylvanian (Upper Carboniferous) strata in the central and Appalachian regions of the United States, and from the Morien (Pictou) Group (Westphalian C and D) of the Sydney coal field, Nova Scotia, Canada. In Europe, this sporophyll is known from the Westphalian B and C.

SPECIMEN: WPMM F667.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Lepidostrobophyllum triangulare (Zeiller), 1888
(Figure 7H, I)

Lepidophyllum triangulare Zeiller, 1886, pl. 77, figs. 4-6; 1888, p. 508.
Lepidostrobus triangularis Zeiller. Arber, 1910, p. 149, pl. 16, fig. 3.
Lepidostrobophyllum triangulare (Zeiller). Bell, 1938, p. 95, pl. 97, figs. 5, 6.
Lepidostrobus triangularis Zeiller. Crookall, 1966, p. 511, pl. 102, fig. 11; text-fig. 145F. (Contains a more complete synonymy.)
Lepidostrobophyllum triangulare (Zeiller). Chaloner and Collinson, 1975, p. 35, fig. G9.

DESCRIPTION: The specimen represents a sporophyll having an elongate triangular lamina, up to 15 mm long and 10 mm wide (greatest width at the base), with nearly straight, or slightly concave, sides; the inferior angles are acute or acutely rounded, and slightly extended beyond the junction with the pedicel. There is a single median vein which is only feebly marked near the acute apex of the lamina. The pedicel is narrow, wedge shaped, and 5 to 8 mm long by 3 to 8 mm broad near the base of the lamina.

REMARKS: There are considerable variations in the ratio of greatest breadth to length of laminae in these isolated sporophylls. The shortest specimens of *Lepidostrobophyllum triangulare* (Zeiller) can be distinguished from *L. brevifolius* (Lesquereux) by their stronger vein and straighter margin, and by the fact that their laminae have sharper apices. Bell (1938, p. 93) found that sporophylls of *L. triangulare* (Zeiller) known from the Nova Scotia coal field are associated with *Lepidodendron dichotomum* Sternberg var. *bretonensis* Bell. He also (1940, p. 127) described *L. triangulare* (Zeiller), a closely related species possibly conspecific with *L. jenneyi* D. White (= *L. anthenis* Koenig).

DISTRIBUTION: *Lepidostrobophyllum triangulare* (Zeiller) is known from Pennsylvanian (Upper Carboniferous) strata in the Appalachian region of the United States and the Morien (Pictou) Group (Westphalian C and D) in the Sydney coal field, Nova Scotia, Canada. In Europe, this sporophyll is fairly common in the Westphalian B and lower C, and rare in the Westphalian upper C and D.

SPECIMEN: WPMM F491.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Family SIGILLARIACEAE
Genus *Sigillaria* Brongniart, 1822
Subgenus *Eusigillaria* Weiss, 1889
Section *Favularia* Sternberg, 1825-1826
Sigillaria elegans Sternberg forma *semipulvinata* Kidston, 1897
(Figure 8A)

Sigillaria semipulvinata Kidston, 1897, v. 39, p. 57, pl. 3, figs. 1-5.
Sigillaria semipulvinata Kidston. Crookall, 1929, p. 30, pl. 8, figs. f, e.
Sigillaria elegans Sternberg var. *semipulvinata* Kidston. Crookall, 1966, p. 367, pl. 82, figs. 1-4; pl. 83, figs. 3-9. (Contains a more complete synonymy.)

DESCRIPTION: The leaf scars on the young specimens occupy the whole upper portion of the leaf cushions. Both the cushions and the scars are transversely rhomboidal, and the lateral angle of the leaf scars meets the margin of the cushions at about halfway between the lateral angle of the leaf cushion and its apex. The cushions are contiguous, 8 mm wide and 4 mm high, separated from the cushions below by a ridge. The lower margin of the leaf scars is rounded; the upper margin is slightly notched. Leaf scars and cushions are ornamented by short, delicate ridges. Two oval cicatricules are situated slightly above the center of the leaf scar, between which is a narrow, slightly lunate, median cicatricule. A minute linear "ligule" scar situated above the median or vascular scar is connected by a notch to the sinus in the upper margin of the leaf scar. The vertical boundaries between rows of cushions are not evident in immature remains.

REMARKS: *Sigillaria semipulvinata* Kidston is a forma (variety) of *S. elegans* Sternberg, which differs from *S. decorata* Weiss in the shape of the cushions; the cushions of the latter are smaller than those of the former. In *S. decorata* the lateral angle of the leaf scar is on the same level as the lateral angle of the cushion, whereas in *S. semipulvinata* it is higher up, meeting the upper margin of the cushion at about its middle.

DISTRIBUTION: In North America, *Sigillaria elegans* Sternberg forma *semipulvinata* Kidston is known only from the Alleghenian and lower Conemaughian (Westphalian C and D); in the Northern Anthracite coal basin it is known from the Westphalian D. In Europe, this variety is rare and is known only from the Westphalian A and B.

SPECIMEN: WPMM F501.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite field, Llewellyn Formation, Baltimore coal bed.

Section *Rhytidolepis* Sternberg, 1823

Sigillaria cf. *elongata* Brongniart, 1825

(Figure 8B, C)

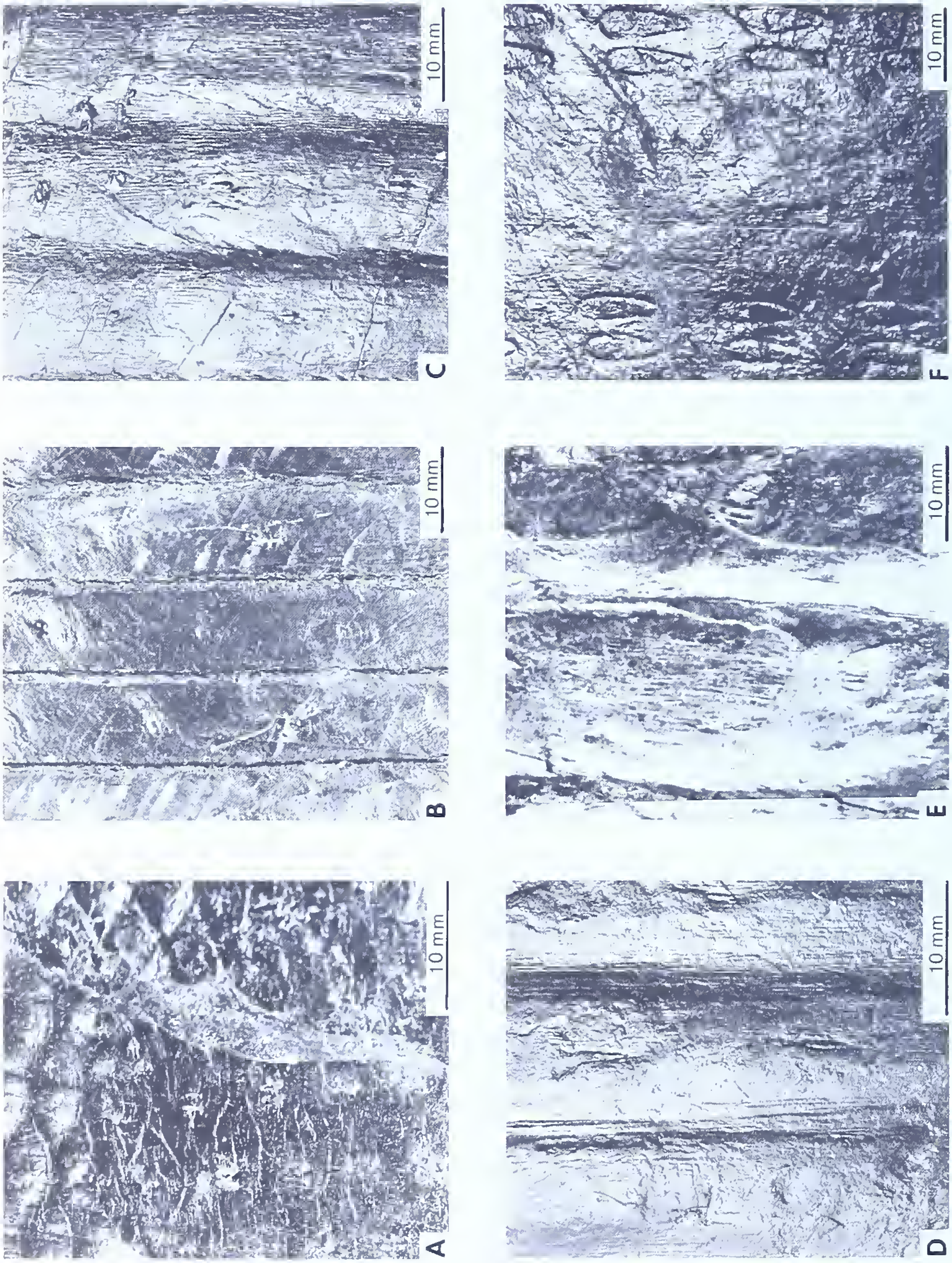
Sigillaria elongata Brongniart, 1825, v. 4, p. 33, pl. 2, fig. 3 (var. minor); fig. 4 (var. major).

Sigillaria elongata Brongniart, 1828a, p. 473, pl. 145 (var. major); pl. 146, fig. 2 (var. minor); 1828b, p. 64, 171.

Sigillaria elongata Brongniart. Zeiller, 1886, pl. 81, figs. 1-9; 1888, p. 545.

Sigillaria elongata Brongniart. Crookall, 1966, p. 414, pl. 88, figs. 6, 7; text-figs. 122, 129. (Contains a more complete synonymy.)

DESCRIPTION: The ribs in the figured specimen are longitudinal, averaging 15 to 17 mm in width, and are slightly convex, bearing longitudinal striae. Furrows separating the ribs are nearly straight and have similar longitudinal striae. Leaf scars are not well preserved, but in general they are pyriform and about 20 mm apart vertically; they are 9 mm long and 4.5 mm broad, occupying about one quarter the breadth of the ribs. Folial cicatricules are located on the same level, down the leaf scars; the central cicatricule or vascular scar is punctiform and the laterals or parichnos scars are linear, arched, and slightly converging upward. The ligule pit is located above the leaf scar, above which extends a transverse line which arches over the leaf scar. The lines that originate from the lateral angles of the leaf scars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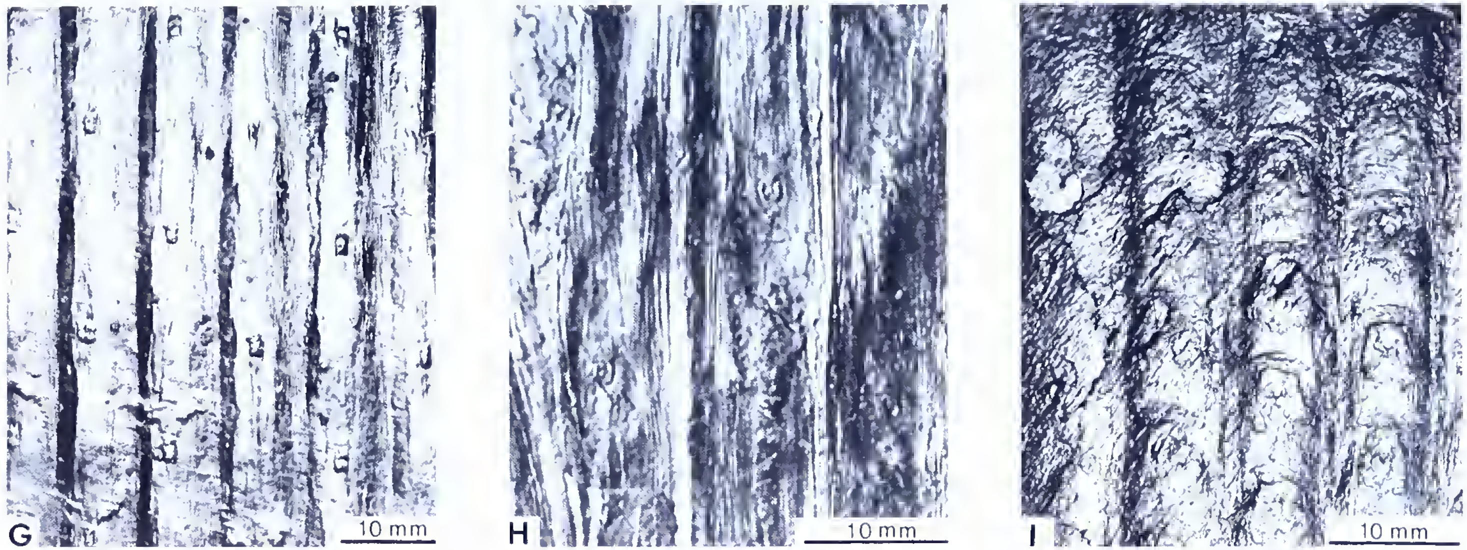


Figure 8. A. *Sigillaria elegans* Sternberg forma *semipulvinata* Kidston [WPMM F501]; B, C. *Sigillaria* cf. *elongata* Brongniart [WPMM F657]; D, E. *Sigillaria laevigata* Brongniart [WPMM F494]; F. "*Syringodendron*" sp. [WPMM F495]; G, H. *Sigillaria rugosa* Brongniart [WPMM F497]; I. *Sigillaria tessellata* Brongniart [WPMM F669].

are slightly divergent and extend downward to about one quarter the distance of the next leaf scar.

REMARKS: Different parts of the stem and also stems of varying degrees of maturity have been described as different species. This explains the confusion among *S. elongata, S. rugosa* Brongniart, and *S. deutschiana* Brongniart. Poorly preserved specimens do not permit accurate determination of the essential characteristics of this species.

DISTRIBUTION: In North America, *Sigillaria elongata* is known from Alleghenian (Westphalian C and D) strata in the Southern Anthracite coal basin of Pennsylvania. In Europe, this species is fairly common in the Westphalian A and B, and less common in the Westphalian C.

SPECIMEN: WPMM F657.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sigillaria laevigata Brongniart, 1828a
(Figure 8D, E)

Sigillaria laevigata Brongniart, 1828a, p. 471, pl. 143, figs. 1, 2A, B; 1828b, p. 64, 66, 172.

Sigillaria laevigata Brongniart. Lesquereux, 1879, pl. 71, figs. 1-3; 1880, p. 500.

Sigillaria laevigata Brongniart. Bell, 1938, p. 102, pl. 103, fig. 4.

Sigillaria laevigata Brongniart. Gothan and Remy, 1957, p. 80, fig. 75; chart 5.

Sigillaria laevigata Brongniart. Crookall, 1966, p. 433, pl. 90, figs. 7, 8; text-figs. 128, 139. (Contains a more complete synonymy.)

DESCRIPTION: The ribs in the figured specimen are longitudinal, slightly convex, 15 to 20 mm in width, and megascopically smooth, but microscopically longitudinally striated. Ribs are separated by very narrow, straight furrows. Leaf scars are about 20 mm apart vertically, are ovate hexagonal, and average 8 mm long and 7 mm broad; the upper margin is rounded, and the lateral angles are distinct. Folial cicatricules are located one third of the way down the leaf scar. The central cicatricule or vascular scar is vertical and elliptical; the ligule pit is located just above the leaf scar. The lateral angles of the leaf scars give rise to delicate lines of decurrence, which bend slightly outward near the scars, but then descend more or less vertically nearly to the leaf scar below.

REMARKS: *Sigillaria laevigata* resembles *S. ovata* Sauver and *S. principis* Weiss. One of the most important characteristics of *S. laevigata* is the absence of a transverse mark above the leaf scar; in *S. ovata* and *S. principis* there is an arched transverse line above the leaf scar.

DISTRIBUTION: *Sigillaria laevigata* occurs in strata ranging from lower Pottsvillian to upper Alleghenian (Westphalian A through D) in the central and Appalachian regions of the United States. It also occurs in the Morien Group of the Pictou coal field in Nova Scotia, Canada. In Europe, this species has a very wide geographical distribution and ranges from the Westphalian A through D; it is rare in the Westphalian A, common in the Westphalian B and C, and rare in the Westphalian D.

SPECIMEN: WPMM F494.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus "*Syringodendron*" Sternberg, 1820

"*Syringodendron*" sp.

(Figure 8F)

Type: *Syringodendron organum* Sternberg, 1820b, p. 22, 24, pl. 13, fig. 1 (decorticated sigillarian stem).

"*Sigillaria*" sp. Arnold, 1947, p. 113, fig. 50.

Syringodendron sp. Gothan and Remy, 1957, p. 77, fig. 66.

DESCRIPTION: The figured specimen represents the remains of a basal portion of a large decorticated sigillarian stem. The extensive growth of the stem is marked by long longitudinal furrows filled with a rocky matrix. The decortication of the outermost tissue of the stem caused the disappearance of the leaf scars that had central (vascular), in most cases punctiform, cicatricules, leaving only the imprint of two lateral cicatricules (parichnos), arranged in vertical rows in a spiral manner. The vertical distance between the parichnos marks, which are arranged in pairs, is about 8 mm, and the distance between vertical rows is about 32 mm, depending upon the stage of growth of the stem. The shape of the parichnos marks is fusiform; therefore, the distance between the parichnos marks in the same pair is about 1.5 mm at one end and about 4 mm at the other. The subepidermal surface of the decorticated stem is marked by coarse longitudinal striae, transected by fine shagreen.

REMARKS: The above-mentioned characteristics indicate that the described specimen is a fragment of a decorticated stem of *Sigillaria laevigata* Brongniart, which belongs to sigillarids having ribbed stems—*Eusigillaria*, section *Rhytidolepis*.

SPECIMEN: WPMM F495.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Sigillaria rugosa Brongniart, 1828a

(Figure 8G, H)

Sigillaria rugosa Brongniart, 1828a, p. 476, pl. 144, fig. 2; 1828b, p. 64, 171.

Sigillaria rugosa Brongniart. Zeiller, 1886, pl. 80, figs. 1-5; 1888, p. 551.

Sigillaria rugosa Brongniart. Gothan and Remy, 1957, p. 80, fig. 69; chart 5.

Sigillaria rugosa Brongniart. Crookall, 1966, p. 443, pl. 92, figs. 6, 7; pl. 93, figs. 1-6; text-figs. 131, 139. (Contains a more complete synonymy.)

DESCRIPTION: The ribs are slightly convex, slightly undulate, about 10 mm wide, and in more mature specimens longitudinally divided into three areas. The central area is rugose down its middle and slightly wider than the leaf scars that it bears; the two lateral areas bear longitudinal striae. Narrow, slightly undulated furrows occur between the ribs and bear delicate, slightly undulate longitudinal striae.

The leaf scars are poorly preserved and oblong-pyriform, tapering toward the top. They average 7 mm in length by 4 mm in width, and generally occupy about three fifths the width of the ribs. Leaf scars are vertically spaced about 20 mm apart. The folial cicatricules consist of a central punctiform cicatricule and two slightly arched lateral cicatricules placed at the same level and converging slightly upward. Two prominent margins extend downward from the lateral angles of the leaf scars; these progressively converge downward and surround an elongated depression approximately two thirds of the distance to the next leaf scar below. In this depression are scattered short, delicate, oblique ribs and punctations.

REMARKS: The width of the ribs and furrows and their shapes and structures vary according to their position and the maturity of the stem. This very often results in confusion in the identification of this species, especially in distinguishing it from *S. elongata* Brongniart and *S. deutschiana* Brongniart. The main differences between these species are the following: (1) *S. rugosa* has elongated leaf-scar markings on the middle zone, a plumose arrangement of lines above the small punctiform cicatricule, and lateral lines from angles of leaf scars extending about two thirds of the distance between the leaf scars downward; (2) *S. elongata* also has elongate leaf scars, but each leaf scar is surmounted by a short lunate scar, above which are transverse lines and elongate punctations, and between the transverse lunate scar and the leaf scar are fine lines placed transversely on each side of the punctiform cicatricule or slightly radiating from it; the lateral lines from the angles of the leaf scars extend downward only for a short distance; (3) *S.*

deutschiana has less elongated leaf scars, is more bell-shaped than the two other species, and has on the middle zone short transverse lines or elongated points, the lateral lines extending down to the leaf scar below.

DISTRIBUTION: In the United States, *Sigillaria rugosa* is known only from the lower portion of the Llewellyn Formation (Westphalian C and D) in the Northern Anthracite coal basin of Pennsylvania. In Europe, this species is known from the Westphalian A through D; it is extremely rare in the Westphalian A, common in the Westphalian B, rare in the Westphalian C, and very rare in the Westphalian D.

SPECIMEN: WPMM F497.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Sigillaria tessellata Brongniart, 1828a
(Figure 81)

Sigillaria tessellata Brongniart, 1828a, p. 436, pl. 156, fig. 1; pl. 162, figs. 1-4; 1828b, p. 65, 171.

Sigillaria tessellata Brongniart. Lesquereux, 1879, pl. 72, figs. 2-4; 1880, p. 481.

Sigillaria tessellata Brongniart. Bell, 1938, p. 98, pl. 100, fig. 2.

Sigillaria tessellata Brongniart. Crookall, 1966, p. 398, pl. 87, figs. 1-4; text-figs. 119, 139. (Contains a more complete synonymy.)

DESCRIPTION: The ribs of the illustrated specimen are slightly undulate and convex, 8 to 9 mm wide. The surface of the decorticated stem is covered by coarse longitudinal striae and crossed by transverse wrinkles; the furrows between the ribs are undulate, less than 1 mm broad. Leaf scars are hexagonal and are two thirds the width of the ribs, averaging 5.5 mm long by 6 mm broad. Lateral angles are generally more or less rounded, and the upper margin is slightly emarginate and flattened by a contiguous transverse arched furrow extending across one half to three quarters of the breadth of the ribs; the basal margin of the leaf scar is truncate. The folial cicatricules consist of a central cicatricule which is punctiform, about 1 mm in diameter, and two laterals, or parichnos scars, located at the same level, which are elliptical. The ligule pit located just above the leaf scar is surmounted by a transverse arched furrow.

REMARKS: *Sigillaria tessellata* is a very variable species; it resembles *S. mammillaris* Brongniart, *S. davreuxi* Brongniart, *S. sauveuri* Zeiller, and some others. Thus, it is often misidentified. The main differences between these species are the shape and the surface pattern of the ribs, the vertical distance of the leaf scars, the length and breadth of the leaf scars, and the shape and length of transverse furrows above the ligule.

The ribs in *S. tessellata* are straight or only slightly undulate; in *S. mammillaris* they are usually undulate, rarely straight; in *S. davreuxi* they are straight or slightly undulate; and in *S. sauveuri* they are straight.

The surface pattern of ribs in *S. tessellata* usually is smooth, but in decorticated specimens there are longitudinal striae, transected by transverse wrinkles; in *S. mammillaris* there are margins below the leaf scars; and in *S. davreuxi* and *S. sauveuri* there are two diverging series of short marks below each leaf scar.

The vertical distance of leaf scars in *S. tessellata* is between 1 and 12 mm; in *S. mammillaris*, 2 and 12 mm; in *S. davreuxi*, 0.5 and 12 mm; and in *S. sauveuri*, 2 and 20 mm.

The length of the leaf scars in *S. tessellata* is 4 to 9.5 mm (average 6 mm); in *S. mammillaris*, 3 to 8 mm (average 5 mm); in *S. davreuxi*, 4 to 10 mm (average 7 mm); and in *S. sauveuri*, 4 to 7 mm (average 4 mm).

Transverse furrows above the ligule crossing the ribs of *Sigillaria tessellata* are one half to three quarters the breadth of the ribs; in *S. mammillaris*, the transverse furrows divide the ribs into segments; in *S. davreuxi*, the transverse furrows are one third to three quarters the breadth of the ribs; and in *S. sauveuri*, the transverse furrows are slightly longer than one half the breadth of the ribs (Crookall, 1966, p. 404, 475).

DISTRIBUTION: In the United States, *Sigillaria tessellata* is found in strata ranging from lower Pottsvillian to lowest Conemaughian (Westphalian A through D), although it is rare in the younger strata. It is known from the bituminous coal fields of Ohio and the anthracite coal basins of eastern Pennsylvania. It is also known from the Morien (Pictou) Group in the Sydney coal field in Nova Scotia, Canada, and from the Minto Formation (Pictou) Group of New Brunswick, Canada. In Europe, this species is common in the Westphalian B and C, but is rare in the Westphalian D.

SPECIMEN: WPMM F669.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Asolanus cf. *camptotaenia* Wood, 1860
(Figure 9A)

Asolanus camptotaenia Wood, 1860b, p. 238, pl. 4, fig. 1.
Sigillaria camptotaenia Wood, 1869, p. 342, pl. 9, fig. 3.

Sigillaria (Asolanus) camptotaenia Wood. White, 1899, p. 230, pl. 69; pl. 70, figs. 1, 3, 4.
Asolanus camptotaenia Wood. Darrah, 1970, p. 182, pl. 34, fig. 1.

DESCRIPTION: The illustrated specimen is a fragment of an impression of an uncostate stem; the surface of the cortex is marked by rounded rhomboidal depressions which indicate the places of attachment of leaves arranged in spiral rows. The area between the leaf scars is ornamented by rough, irregular, coarse-meshed cortical strands, some of them radiating from each leaf scar; the intermediate strands in the rhomboidal areas are subparallel. The impressions of the leaf scars vary greatly in angle even in the same segment; they are transversely rhomboidal, and have acute lateral angles and well-rounded upper and lower corners, the upper more broadly rounded than the lower. The leaf scars are about twice as broad as high (6 mm broad and 3 mm high); the upper margin has an inconspicuous minute central notch in the form of a V-shaped depression. In the upper half of the leaf scar is a vascular circular scar, about 1 1/4 mm in diameter, which has within it or close to its upper margin a punctiform scar; lateral cicatricules, slightly distant on each side of the vascular scar, are narrow and linear-crescentic, reaching nearly to the upper and lower margins of the leaf scars.

REMARKS: *Asolanus camptotaenia* is a peculiar type of *Sigillaria* (Wood, 1869). It is distinguished from the other species in the group Subsigillariae (Sterzel, 1895) by the concave lateral margins of the distant leaf scars; the attenuated lateral angles; the very long, linear-crescentic lateral cicatricules extending nearly the whole height of the scar and forming an obovate ring; and the coarse- (rope-) meshed cortical strands.

DISTRIBUTION: *Asolanus camptotaenia* is one of the more familiar and most easily recognized species in the coal fields of North America. This species ranges from the middle Pottsvillian to the upper Monongahelan (Westphalian B to Stephanian C), but it is less frequent in the Monongahelan. It is known from the central and Appalachian regions of the United States, from the Morien (Pictou) Group of Nova Scotia, Canada, and from the Minto Formation (Pictou Group) of New Brunswick, Canada. In Europe, this species is known from the upper Westphalian B and the Westphalian C and D.

SPECIMEN: WPMM F502.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

"Genus" *Cyperites* Lindley and Hutton, 1832
Cyperites bicarinatus Lindley and Hutton, 1832
(Figure 9B)

Cyperites bicarinata Lindley and Hutton, 1832, p. 123, pl. 43, figs. 1, 2.

Cyperites bicarinatus Lindley and Hutton. Unger, 1850, p. 313.
Cyperites bicarinatus Lindley and Hutton. Crookall, 1966, p. 534, pl. 105, fig. 7; text-fig. 153. (Contains a more complete synonymy.)

DESCRIPTION: This provisional genus represents a sterile leaf of some arborescent lycopod. The leaf is long, grasslike, pointed at the apex, and thickened at the base. In most cases, the specimens are fragmentary. A single median vein runs down the center of the leaf, and on each side of this is evident a strong line which represents the stomatal groove; the margin of the leaf is entire.

REMARKS: *Cyperites bicarinatus* very often is associated with specimens of *Sigillaria elongata* Brongniart, *S. rugosa* Sternberg, and *Lepidodendron aculeatum* Sternberg, which suggests that this leaf belongs to one of these species. The generic name is unfortunately misleading, because it implies a relationship to modern grasses (Gramineae), sedges, and grasslike plants (Cyperaceae).

DISTRIBUTION: *Cyperites bicarinatus* is common in the Pennsylvanian (Upper Carboniferous) strata, where the above-mentioned lycopods are found.

SPECIMEN: WPMM F500.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

"Genus" *Stigmaria* Brongniart, 1822

Stigmaria ficoides (Sternberg) Brongniart, 1822

(Figure 9C, D)

Variolaria ficoides Sternberg, 1820b, p. 22, 24, pl. 12, figs. 1-3.
Stigmaria ficoides (Sternberg) Brongniart, 1822, p. 228, 239, pl. 1, fig. 7; 1828b, p. 88, 174.
Stigmaria ficoides (Sternberg) Brongniart. Bell, 1938, p. 103, pl. 105, fig. 8.
Stigmaria ficoides (Sternberg) Brongniart. Crookall, 1966, p. 549, pl. 104, figs. 1-3; pl. 105, figs. 1, 2; pl. 106, fig. 5; text-figs. 155a, b, 156. (Contains a more complete synonymy.)
Stigmaria ficoides Brongniart. Darrah, 1970, p. 181, pl. 27, fig. 3.

DESCRIPTION: This fossil is represented by a few fragments of flattened casts of underground organs (rhizomes), 4 to 6 cm in diameter, some having attached rootlets (rhizoids). In most fragments the surface of the rhizomes is nearly smooth and bears more or less circular (some are elliptical in cross section), spirally arranged traces of rhizoids, 6 to 8 mm apart. The rootlet scar has a slightly raised rim surrounding a circular depression, in the middle of which is a small raised central projection, a vascular cicatrice. The rootlets arise nearly at right angles from the rhizome, and generally are 6 to 8 mm in breadth at their bases and about 15 cm or more in length. The rootlets near their bases are gradually tapering cylinders with an evident central scar of the vascular bundle; farther from their bases they have a ribbonlike form. No root hairs were observed.

REMARKS: *Stigmaria* occurs in all kinds of fossiliferous strata, but is more common directly beneath the coal beds in siltstones or mudstones (seat earths), which represent the original topsoil in which the coal-swamp plants were rooted. The stigmarian remains are seldom petrified; they exist mostly as siltstone- or mudstone-filled cylindrical casts surrounded by a thin crust of carbonaceous material.

DISTRIBUTION: *Stigmaria ficoides* is a common fossil in certain horizons of Carboniferous strata, especially in association with the seat earths of coal seams in the central and Appalachian coal fields; in the Narragansett basin of New England; in the Morien (Pictou) Group of the Sydney coal field of Nova Scotia, Canada; and in the Minto Formation (Pictou Group) of New Brunswick, Canada. In Europe, *S. ficoides* is very common at certain horizons of Carboniferous strata, especially in the seat earth below coal seams.

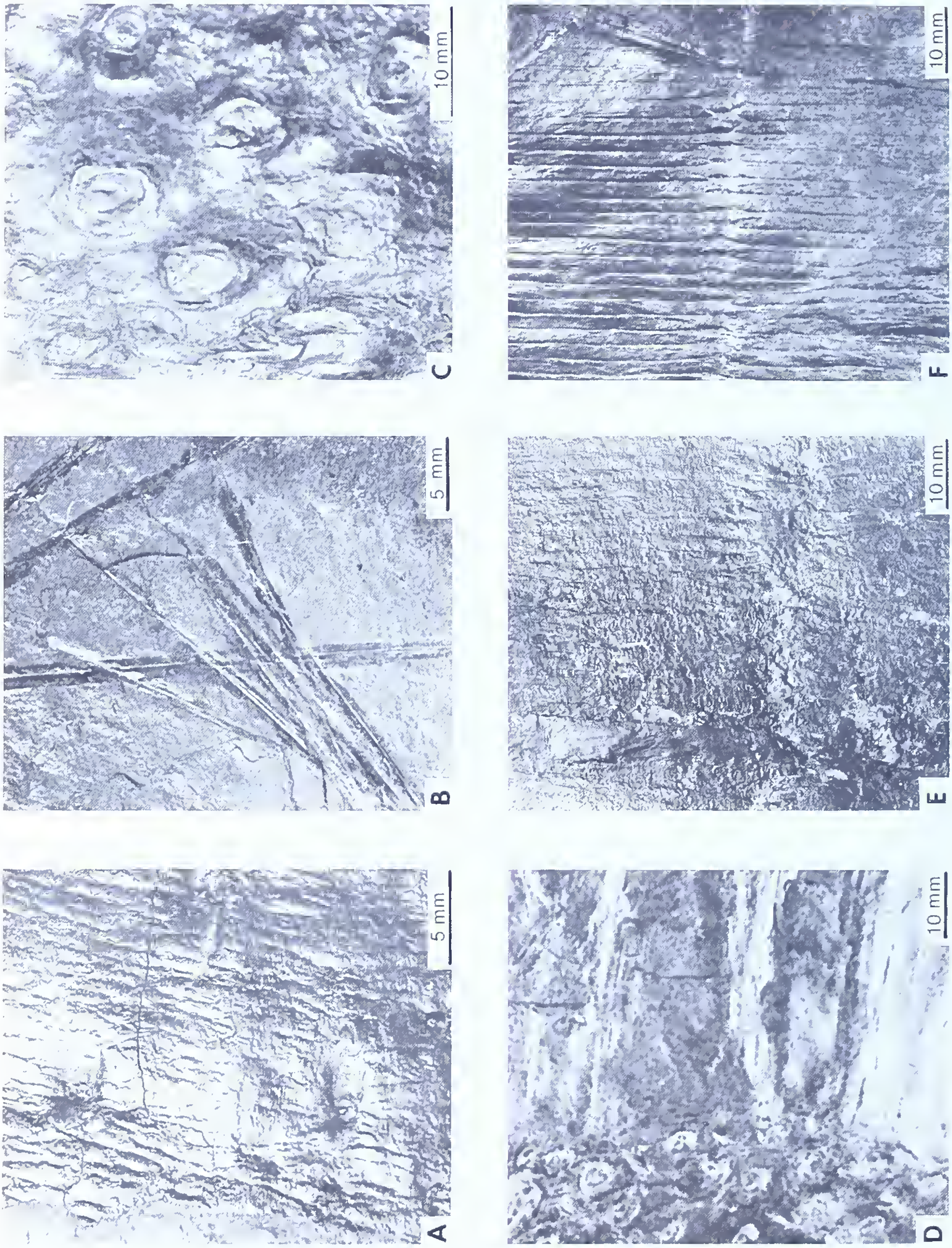
SPECIMENS: WPMM F503, F504.

LOCALITIES: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed; and Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Subphylum EQUISETOPHYTA
Class SPHENOPSIDA (ARTICULATAE)
Order CALAMARIALES
Family CALAMITACEAE
Genus *Calamites* Suckow, 1784
Calamites carinatus Sternberg, 1824
(Figure 9E)

Calamites carinatus Sternberg, 1824, p. 36, 39, pl. 32, fig. 1.
Calamites carinatus Sternberg. Abbott, 1968, p. 21, pl. 15, figs. 1, 2.
Calamites carinatus Sternberg. Darrah, 1970, p. 170, pl. 35, fig. 2.
Calamites carinatus Sternberg. Oleksyshyn, 1976, p. 152, fig. 5B.

DESCRIPTION: The species is represented by pith casts having internodes that are nearly always longer than broad; the pith casts are up to 13 cm long and 10 cm wide, and have rough cortexes. The flattened ribs, bearing fine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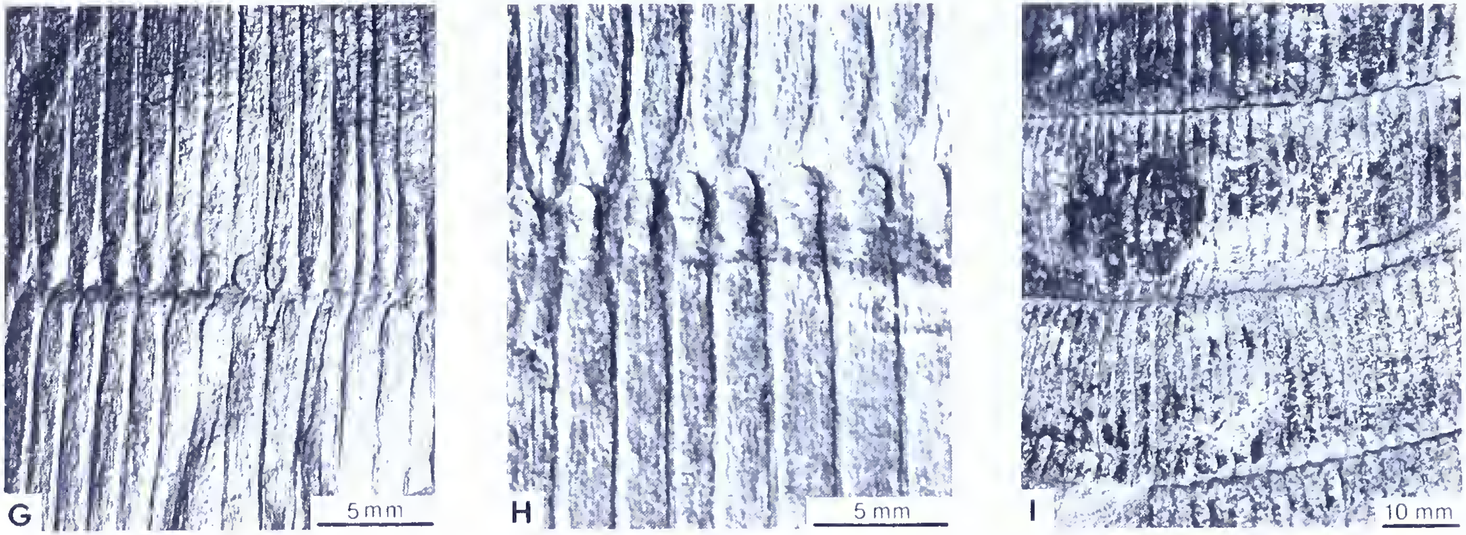


Figure 9. A. *Asolanus* cf. *camptotaenia* Wood [WPMM F502]; B. *Cyperites bicarinatus* Lindley and Hutton [WPMM F500]; C, D. *Stigmaria ficoides* (Sternberg) Brongniart [WPMM F503, F504]; E. *Calamites carinatus* Sternberg [WPMM F672]; F, G, H. *Calamites cistii* Brongniart [WPMM F451, F673]; I. *Calamites schuetzeiformis* Kidston and Jongmans forma *typica* [WPMM F674].

longitudinal striae, alternate in neighboring internodes and bend toward the slightly constricted nodes; the ribs are separated by broad double-lined furrows. Tubercules at the upper ends of the ribs are oval and are rarely seen. Branch scars, to which two or three neighboring ribs converge, are typically oval-triangular; they occur in most specimens as two oppositely placed scars on each node. The scars of each alternate node occur immediately above each other.

REMARKS: *Calamites carinatus* is very similar to *C. paleaceus* Stur, which has double-lined furrows on the pith casts. The centers of the branch scars are remarkably small, only about 1 mm across, whereas in *C. carinatus* they are large, averaging about 13 mm. The leaves of *C. carinatus* belong to *Annularia radiata* Brongniart and the cones belong to the "genus" *Calamostachys* ("species" *C. ramosa*). The leaves of *C. paleaceus* are of the *Asterophyllites* type and the cones are the same as *Metacalamostachys paleaceus* Stur, which resembles *Volkmania pseudosessilis* Grand'Eury (Crookall, 1969, p. 688).

DISTRIBUTION: In North America, *Calamites carinatus* ranges from lower Pottsvillian to Monongahelan (Westphalian A to Stephanian B or C). The fossil records are known from the central and Appalachian regions and from the Narragansett basin in the United States. They are also known from the Riversdale Group (Westphalian A) and from the Morien (Pictou) Group (Westphalian C and D) of the Maritime region of eastern Canada. In Europe, this species is rare in the Namurian, common in the Westphalian A, B, and lower C, and less common in the Westphalian upper C and D.

SPECIMEN: WPMM F672.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Calamites cistii Brongniart, 1828a
(Figure 9F, G, H)

Calamites cistii Brongniart, 1828a, p. 129, pl. 20, figs. 1-5; 1828b, p. 38, 167.

Calamites cistii Brongniart. Lesquereux, 1879, pl. 1, fig. 6; 1880, p. 27.

Calamites cistii Brongniart. Gothan and Remy, 1957, p. 45, 46, fig. 35; chart 5.

Calamites cistii Brongniart. Oleksyshyn, 1976, p. 152, fig. 5C, D.

DESCRIPTION: The species is represented by pith casts having slightly constricted nodes and internodes that are, in most specimens, broader than long. The ribs are straight, about 1 mm across, alternating at the nodes, and longitudinally striated, having subacute or blunt ends; they are bounded by narrow, straight furrows that have a prominent line on each side. Tubercules, about 2 mm long and 1 mm broad, are located at the upper ends of the ribs, and smaller circular tubercules are occasionally found at the lower ends.

REMARKS: *Calamites cistii* has some similarities to *C. dubius* Artis, *C. suckowii* Brongniart, and *C. undulatus* Sternberg. *Calamites dubius*, like *C. cistii*, has double-lined furrows which separate the ribs, but the nodes of the former are very contracted. The nodes in *C. suckowii* and *C. cistii* are only slightly contracted, but the former species has no double-lined furrows and the upper tubercules are larger than in *C. cistii* and are circular rather than elliptical; the ends of ribs at the nodes are more rounded than in *C. cistii*. The main difference between C. *undulatus* and *C. cistii* is that the former species lacks double-lined furrows and has cross-hatching on the ribs.

DISTRIBUTION: *Calamites cistii* is known from Alleghenian and lower Conemaughian (Westphalian C and D) strata in the central and Appalachian regions, and from the Narragansett basin in the United States; it is also known from the Riversdale Group (Westphalian A) in New Brunswick, Canada, and from the Cumberland Group (Westphalian B_1) in Nova Scotia, Canada. In Europe, this species ranges from the Namurian C through the Westphalian into the Stephanian and Lower Rothliegend (Permian).

SPECIMENS: WPMM F451, F673.

LOCALITY: Wanamie, near Wilkes Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Calamites schuetzeiformis Kidston and Jongmans forma *typica*, 1913
(Figures 9I, 10A)

Calamites approximatus Artis, 1825, p. 10, pl. 4.
Calamites schuetzeiformis forma *typicus* Kidston and Jongmans, 1913, in Jongmans and Kukuk, 1913, p. 32; text-fig. 2.
Calamites schuetzeiformis Kidston and Jongmans forma *typicus* Kidston and Jongmans, 1917, p. 92-97; pl. 68, fig. 1; pl. 71, fig. 3; pl. 73, fig. 5; pl. 74, fig. 1; pl. 75, figs. 1, 2; pl. 79, figs. 1, 2; pl. 80, figs. 1, 2; text-figs. 52-57.

DESCRIPTION: The species is represented by pith casts having internodes of unequal length, 1 to 6 cm long and 7 to 10 cm broad. The internodes are more or less convex, and constricted at the nodes; the internodes immediately above the branch whorl are usually the shortest and those just below the branch whorl are generally the longest. The ribs are prominent, flat, 1.5 to 2 mm wide, straight, and truncated at the nodes. The furrows separating the ribs are narrow; tubercules are obscure. The branch scars are circular and are about 3 mm in diameter.

REMARKS: *Calamites schuetzeiformis* forma *typica* is very similar to *C. schuetzeiformis* forma *intermedia* and C. *schuetzeiformis* forma *waldenburgensis* (= *C. approximatus* Artis). The difference is mainly in the length of the internodes. In *C. schuetzeiformis* forma *typica* the internodes are unequal in length; the one immediately above the branch whorl is usually the shortest and the one located below the branch whorl is usually the longest. In *C. schuetzeiformis* forma *intermedia* the internodes above and below the branch whorl are usually the longest, and in *C. schuetzeiformis* forma *waldenburgensis* (= *C. approximatus*) all internodes are approximately of equal length and that below the branch whorl is the longest.

DISTRIBUTION: *Calamites schuetzeiformis* forma *typica* is fairly common in the Northern Anthracite coal basin of Pennsylvania in the uppermost Alleghenian (Westphalian D) strata. In Europe, this species is known from the Westphalian B, C, and D.

SPECIMENS: WPMM F674, F456.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus *Asterophyllites* Brongniart, 1822

Asterophyllites equisetiformis (Schlotheim) Brongniart, 1822

(Figure 10B, C)

Casuarinites equisetiformis Schlotheim, 1820, p. 397.

Asterophyllites equisetiformis (Schlotheim) Brongniart, 1822, p. 210.

Asterophyllites equisetiformis (Schlotheim). Lesquereux, 1879, pl. 2, figs. 3, 3a; 1880, p. 35.

Asterophyllites equisetiformis (Schlotheim) Brongniart. Abbott, 1958, p. 299, pl. 35, fig. 4; pl. 36, figs. 12, 15, 19, 20; pl. 39, figs. 46, 47, 49-51; pl. 43, fig. 63; pl. 47, fig. 78; chart 1.

Asterophyllites equisetiformis Schlotheim forma *typica* sensu Jongmans and Kidston. Crookall, 1969, p. 695, pl. 142, fig. 3, text-fig. 203. (Contains a more complete synonymy.)

Asterophyllites equisetiformis (Schlotheim) Brongniart. Lyons and Darrah, 1978, p. 437, fig. 3E, G.

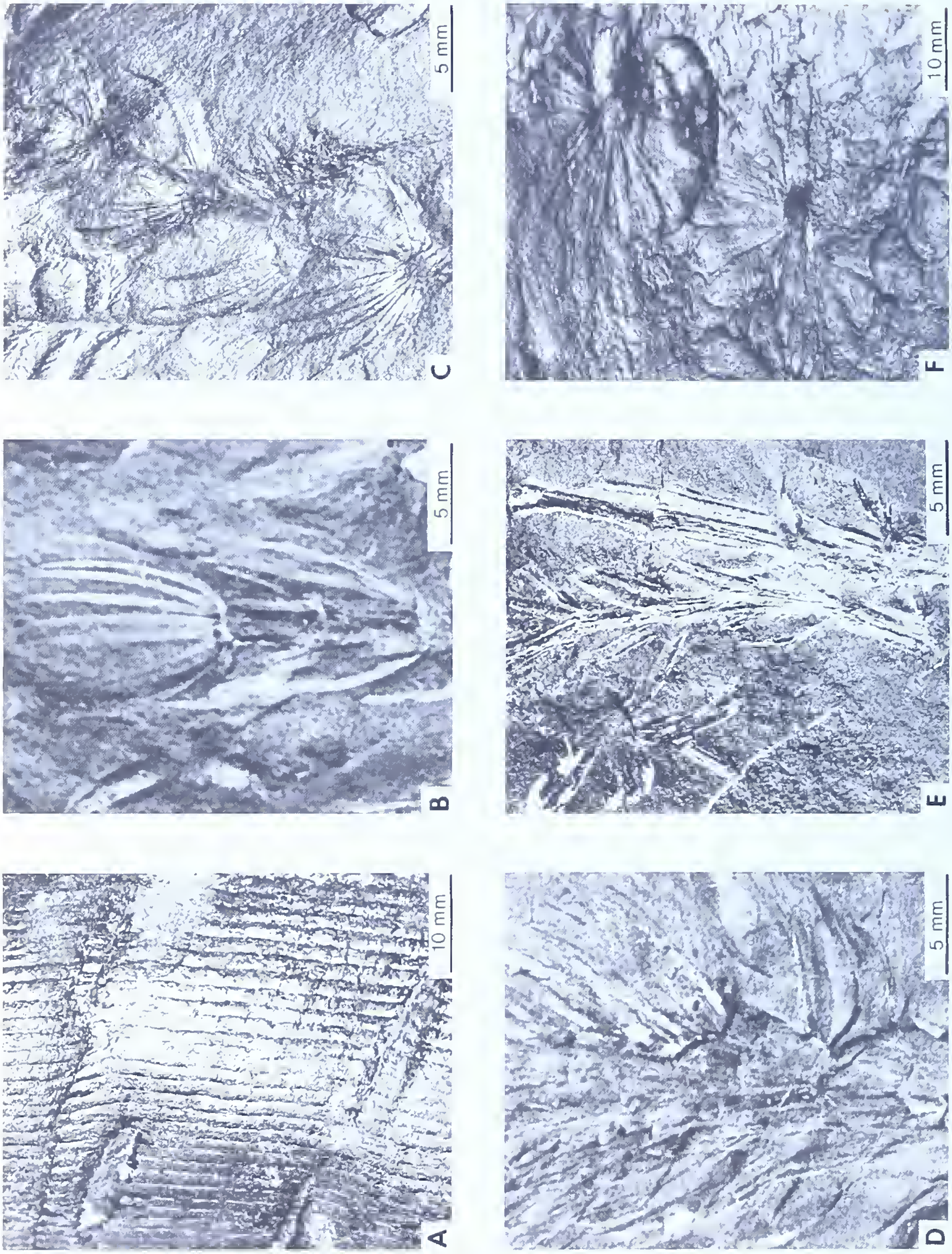
DESCRIPTION: The penultimate branches of the stem are radially symmetrical and have longitudinally ribbed internodes 5 to 18 mm long and 2.5 mm wide. The nodes, some of which are slightly enlarged, bear 12 to 20 linear-lanceolate, uninerved leaves about 15 mm long and 0.5 mm wide in their middle portion, with sharply pointed apices. The leaves in the lower portion of the stem are attached to the nodes at greater angles, and in the upper portion, where the internodes become shorter and thinner, the leaves also become smaller, nearly straight for most of their length, and attached at successively smaller angles to the nodes. Near the tips of the ultimate, flexuous shoots, which have internodes about 2.5 mm long and 0.7 mm wide, there are slightly enlarged nodes from which arise small leaves, about 4 mm long; these leaves are crowded together, forming a "paint brush" appearance.

REMARKS: The difference between *Asterophyllites equisetiformis* and *A. longifolius* (Sternberg) Brongniart is that the leaves on the penultimate branches of the stem of the former species, 12 to 20 per whorl, are linear-lanceolate and widest at the middle, having one margin convex and a median vein ranging from one fourth to one half the width of the leaf; in the lower portion of the branch the leaves are inclined to the stem at a wide angle, nearly 90 degrees, but in the upper portion this angle diminishes to about 30 degrees or less. The leaves of *A. longifolius* are much longer, more linear, and straighter, having a median vein about one half the width of the leaf; the leaves usually are inclined to the stem at about 45 degrees in the older parts of the stem.

The difference between *A. equisetiformis* and *A. grandis* (Sternberg) Geinitz is that the main stem of the latter species may be 11 to 20 mm wide and the internodes about 13 mm long. The leaves of *A. grandis*, 16 to 20 in a whorl, are linear-falcate and widest at the base. A relatively strong midvein occupies nearly one half the width of the leaf. The leaves on the older stems are shorter than the internodes and those on the younger branches are longer than the internodes; the leaves are inclined to the stem at about 90 degrees and curve in their upper portion toward the stem.

The difference between *A. equisetiformis* and *A. charaeformis* (Sternberg) Goeppert is that the leaves of the latter species are very small, falcate, and widest at the base; the midvein is about one half the width of the leaf. In their lower portion, the leaves are inclined at an angle of approximately 90 degrees to the stem at the nodes, but in their middle and upper portions, they curve abruptly upward and parallel the axis.

DISTRIBUTION: In North America, *Asterophyllites equisetiformis* ranges from Pottsvillian through Alleghenian (Westphalian A, B, C, and D). In the United States, this species is known from coal basins of the central and Appalachian regions and from the Narragansett basin. It is also known from the Riversdale (Westphalian A), Cumberland (lower Westphalian B), and Morien (Pictou) Groups (Westphalian C and D) in Nova Scotia, Canada. In Europe, this species ranges from the Westphalian A to the Rothliegend (Lower Permian), but it is most common in the Westphalian A and B, and rare in the Westphalian C and D.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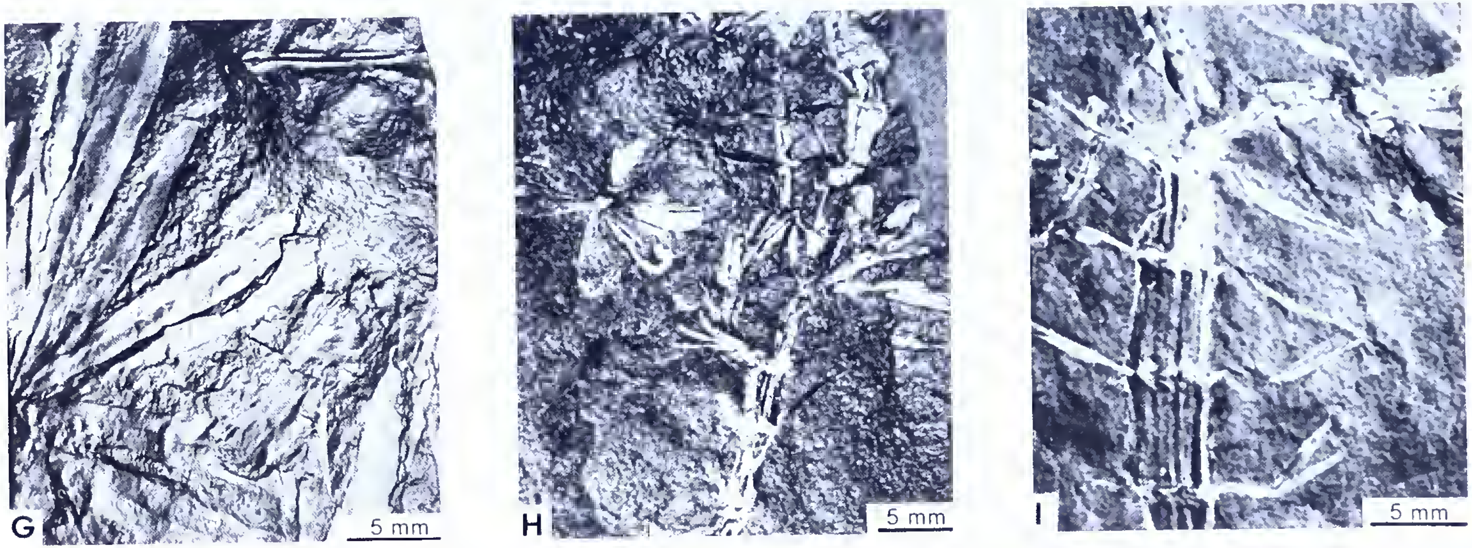


Figure 10. A. *Calamites schuetzeiformis* Kidston and Jongmans forma *typica* [WPMM F456]; B, C. *Asterophyllites equisetiformis* (Schlotheim) Brongniart [WPMM F458]; D, E. *Asterophyllites longifolius* (Sternberg) Brongniart [WPMM F648, F660]; F. *Annularia mucronata* Schenk [WPMM F460]; G. *Annularia stellata* (Schlotheim) Wood [WPMM F612]; H, I. *Sphenophyllum cuneifolium* (Sternberg) Zeiller [WPMM F464, F680].

SPECIMEN: WPMM F458.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Asterophyllites longifolius (Sternberg) Brongniart, 1828b
(Figure 10D, E)

Bruckmannia longifolia Sternberg, 1825, p. 50, XXIX, pl. 58, fig. 1a, b.
Asterophyllites longifolia (Sternberg) Brongniart, 1828b, p. 159, 176.
Asterophyllites longifolius (Sternberg) Brongniart. White, 1899, p. 153, pl. 49, figs. 2-4.
Asterophyllites longifolius (Sternberg) Brongniart. Abbott, 1958, p. 303, pl. 40, fig. 53; pl. 42, fig. 60; chart 5.
Asterophyllites longifolius Sternberg forma *typica*. Crookall, 1969, p. 704, pl. 150, fig. 2; text-fig. 205. (Contains a more complete synonymy.)

DESCRIPTION: The species is represented by strong, leafy calamitic shoots that have longitudinally ribbed internodes, 18 to 20 mm in length, 5.5 to 6 mm wide at the nodes, and 4 mm wide below the nodes. The linear, rigid leaves with sharp tips, 30 to 40 in a verticil, measure 3 to about 4.5 cm in length by 1 mm or less in breadth. At the middle of each leaf, an evident midvein forms a low, keel-like structure or carina. The leaves arise from the nodes at about 45 degrees to the axis and curve upward.

REMARKS: *Asterophyllites longifolius* differs from *A. equisetiformis* (Schlotheim) Brongniart in that the internodes of the latter are much shorter, averaging 10 mm in length; also the leaves of the latter are linear-lanceolate and much shorter, about 12 mm long, and arise from the nodes usually at much greater angles, 30 to 90 degrees.

DISTRIBUTION: In North America, *Asterophyllites longifolius* ranges from Pottsvillian to upper Alleghenian (Westphalian A to D). This species is known from the central and Appalachian regions in the United States, from the Cumberland Group (lower Westphalian B) and the Morien (Pictou) Group (Westphalian C and D) in Nova Scotia, Canada, and from the Minto Formation (Pictou Group) (Westphalian C and D) in New Brunswick, Canada. In Europe, this species is recorded from the Westphalian A, B, C, and D.

SPECIMENS: WPMM F648, F660.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Genus *Annularia* Sternberg, 1823
Annularia mucronata Schenk, 1883
(Figure 10F)

Annularia mucronata Schenk, 1883, p. 226, pl. 30, fig. 10; text-fig. 10.
Annularia stellata (Schlotheim) forma *mucronata* Schenk. Bell, 1938, p. 85, pl. 89; pl. 91, fig. 1.
Annularia mucronata Schenk. Abbott, 1958, p. 315, pl. 35, fig. 5; pl. 36, figs. 10, 11, 14, 16-18; pl. 41, fig. 57; pl. 42, figs. 59, 61; chart 2.
Annularia mucronata Schenk. Oleksyshyn, 1976, p. 154, fig. 6C, D, E.

DESCRIPTION: The spatulate leaves, about 16 in a verticil, are 6 to 16 mm long and 1.5 to 3 mm broad; they are widest near the apex. The leaves in the verticil are of unequal length; those nearer to right angles to the stem are almost twice as long as those that nearly parallel the stem. Such an arrangement of leaves gives the whorls an oval shape, rather than circular, with the greatest diameter at right angles to the stem. The lateral margins of the leaves are straight and the width of the blades increases from the sheath near the node, marked by a small ring about 1.5 mm in width, to the broadly rounded and strongly mucronate tips. Some leaves may have obtuse or obcordate apices due to burial in the matrix. The leaves are single-veined; the strong midvein is about one fifth of the leaf width and flares out at the tip of the leaf.

REMARKS: The size of the leaves of *Annularia mucronata* is intermediate between *A. stellata* (Schlotheim) Wood and *A. sphenophylloides* (Zenker) Gutbier. Some confusion in the identification may be due to their mode of preservation as fossils, especially when they are more or less buried in the matrix. For this reason Zeiller (1888), White (1899), and Kidston (1903) united *A. mucronata* with *A. stellata*. The main differences between these species are in the size, shape, variation, and number of leaves in the whorl and their internodal spacing.

The maximum length of the leaves of *A. mucronata* may be 25 mm, whereas those of *A. sphenophylloides* are only a maximum of 12 mm long; those of *A. stellata* may reach as much as 75 mm in length. The leaves of *A. mucronata* are spatulate in shape and have distinctly mucronate apices, whereas in *A. sphenophylloides* the leaves are also spatulate and mucronate but have more broadly rounded apices; the leaves of *A. stellata* are oblanceolate and mucronate, but have obtusely pointed apices. The leaves of *A. mucronata,* 10 to 24 in a whorl, are widely spaced, whereas in *A. sphenophylloides* there are 10 to 20 leaves in a whorl and they are more closely spaced. In *A. stellata,* the leaves are oblanceolate, 13 to 32 in a whorl, and are slightly arched and joined together at the base to form a sheath around the stem. The whorls of *A. mucronata* are progressively larger from the apex to the base of the stem, whereas those of *A. sphenophylloides* are more uniform in size.

DISTRIBUTION: In North America, *Annularia mucronata* ranges from Alleghenian (Westphalian C) to mid-Dunkardian (Lower Permian). This species is known from the central and Appalachian regions and from the Narragansett basin of New England. It is also known from the *Linopteris obliqua* Zone of the Sydney coal field (Westphalian C) in Nova Scotia, Canada.

SPECIMEN: WPMM F460.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Annularia stellata (Schlotheim) Wood, 1860
(Figure 10G)

Casuarinites stellatus Schlotheim, 1820, p. 397.

Annularia stellata (Schlotheim) Wood, 1860, p. 236.

Annularia stellata (Schlotheim) Wood. Abbott, 1958, p. 321, pl. 35, fig. 1; pl. 36, figs. 8, 9; pl. 41, fig. 58; pl. 43, figs. 62, 64; pl. 49, fig. 87; chart 2.

Annularia stellata Schlotheim. Gothan and Remy, 1957, p. 51, figs. 40, 41; chart 5.

Annularia stellata (Schlotheim) Wood. Darrah, 1970, p. 172, pl. 37, fig. 1.

DESCRIPTION: The leaves in the figured specimen are oblanceolate, mucronate, and obtusely pointed, 13 to 32 in a whorl, ranging from 24 to 29 mm in length and 2 to 3 mm in width; the maximum width is near or above the middle. The leaves in the whorl are usually of unequal length; the lateral leaves at right angles to the stem are longer than those parallel to it. Thus, whorls tend to be elliptical rather than circular. The adjacent whorls, as preserved, usually touch or even partially overlap each other. The broad, distinct midvein, 0.3 to 0.5 mm wide, occupies about one fifth of the width of the leaf.

REMARKS: The great variation in the length and number of leaves in the whorls, as well as in the mode of preservation of *A. stellata,* caused many erroneous interpretations of this species. *Annularia longifolia* Brongniart has been placed by Wood (1860) in the synonymy with *A. stellata.* Lesquereux (1870) proposed the species *A. inflata* for specimens with leaves having rounded or subcylindrical form and margins incurved toward the adaxial surface, and in which the midrib was obscured. Later Stur (1887) assigned this species to *A. stellata.*

DISTRIBUTION: *Annularia stellata* is a cosmopolitan species ranging from Pottsvillian to Dunkardian (Westphalian A to Lower Permian). In the United States it is known from the central and Appalachian regions; in Canada it is known from the Cumberland Group (Westphalian B_1) of Nova Scotia, the Pictou Group of New Brunswick, and the Morien (Pictou) Group (Westphalian C and D) in the Sydney coal field of Nova Scotia. In Europe, this species is rare in the Westphalian A, B, and lower C, but more common in the Westphalian D through the Stephanian to the Rothliegend (Lower Permian). It is known also from contemporaneous strata in China and Korea.

SPECIMEN: WPMM F612.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Order SPHENOPHYLLALES
Family SPHENOPHYLLACEAE
Genus *Sphenophyllum* Brongniart, 1822
Sphenophyllum cuneifolium (Sternberg) Zeiller, 1880
(Figures 10H, I; 11A, B)

Rotularia cuneifolia Sternberg, 1823, p. 23, pl. 26, fig. 4a, b.

Sphenophyllum cuneifolium (Sternberg) Zeiller, 1879, pl. 161, figs. 1, 2; 1880, p. 30.

Sphenophyllum cuneifolium Sternberg. Gothan and Remy, 1957, p. 59, 60, fig. 49; chart 5.

Sphenophyllum cuneifolium (Sternberg) Zeiller. Abbott, 1958, p. 336, pl. 37, fig. 22; pl. 38, fig. 36; chart 3.

Sphenophyllum cuneifolium Sternberg. Crookall, 1969, p. 579, pl. 107, fig. 5; pl. 109, figs. 3, 4, 13, 14; text-figs. 160-162, 163a, 171a. (Contains a more complete synonymy.)

Sphenophyllum cuneifolium Sternberg. Lyons and Chase, 1976, fig. 4E.

DESCRIPTION: This species consists of a narrow, laterally branching stem having whorls of heterophyllous leaves at the nodes. The leaves near the apices of the stems are wedge shaped and average 12 mm in length and 5 mm in width at the apex. There are commonly six to twelve leaves per whorl, spreading out from the node. Lateral margins are straight to slightly convex; distal margins are straight to slightly arching. The distal margin of the leaves may be entire or may have a median notch, 1.5 to 2.5 mm deep and bearing from 6 to 14 sharp, triangular teeth. The leaves in the older portion of the stem are centrally dissected into progressively deeper clefts, some almost to the base of the leaf, forming four fingerlike, sharply pointed lobes.

A single vein enters the base of the leaf and in undivided leaves dichotomizes three to four times, a veinlet entering each tooth of the distal margin. In more dissected leaves, a single vein enters the base and divides only two to three times. Based on the degree of dissection of the leaves, two different forms of this species are recognized. The most common is *S. cuneifolium* forma *typica,* whose leaves have lateral margins slightly concave or straight. The distal margins are nearly straight and are either entire or have a small median notch, which in some specimens is about 1.5 to 2.5 mm deep, and which bears from 6 to 14 sharp, triangular teeth. A single vein enters the base of each leaf and divides three or four times. *Sphenophyllum cuneifolium* forma *saxifragaefolium* Goeppert has leaves with lateral margins markedly concave and distal margins divided into two or four long, tapering lobes; a single vein enters the base of each leaf and divides only two or three times.

The older stems are longitudinally ribbed in an irregular fashion; the leaves are dissected into long, tapering lobes 2.5 to 3 mm thick, and the internodes are about 15 mm long. Younger stems bear undissected leaves or have one small median notch, about 1 mm in depth; internodes are about 10 mm long. The stems branch rather sparingly, with a single branch at the node. Fructifications are not preserved.

REMARKS: There are some superficial similarities between *S. cuneifolium, S. emarginatum* Brongniart, and *S. verticillatum* (Schlotheim) Zeiller, especially when the distal margins of their leaves are embedded in the rocky matrix or the apices of the leaves are broken. When entire leaves are preserved, *Sphenophyllum cuneifolium* is easy to distinguish from *S. emarginatum,* because the leaves of the former species on the young stems are wedge shaped and large and have sharp teeth on their distal margins, whereas the latter species has smaller, rounded teeth. The main difference between *S. cuneifolium* and *S. verticillatum* is that the leaves of the former species on the young stems are wedge shaped and wide, having straight or slightly arching distal margins and sharp teeth, whereas the leaves of the latter species are narrowly triangular, having arching distal margins and obtusely dentate teeth. *Sphenophyllum majus* (Bronn) Bronn has larger leaves with more numerous, longer, blunter teeth and two veins at the base of the leaf.

The fragments of dissected leaves of *S. cuneifolium* forma *saxifragaefolium* from the older portion of the stem may easily be confused with leaves of *S. angustifolium* (Germar) Goeppert, which also have long, pointed teeth, but are more narrowly cuneate and sometimes only trilobed. The fragments of dissected leaves of *S. cuneifolium* also may be confused with dissected leaves of *S. oblongifolium* (Germar and Kaulfuss) Unger. The main difference is that in the former species all leaves are of the same length, whereas in the latter species there is a trizygoid leaf arrangement, the broadest part of the leaf is in the middle, and the lateral margins of the leaf are convex.

DISTRIBUTION: In North America, *Sphenophyllum cuneifolium* ranges from lower Pottsvillian (Westphalian A) to lower Conemaughian (Westphalian D). It is known from the central and Appalachian regions of the United States and from the Riversdale Group (Westphalian A) in Nova Scotia and the Pictou Group (Westphalian C and D) in New Brunswick and Nova Scotia, Canada. In Europe, this species is common in the Westphalian A, very common in the Westphalian B, rare in the Westphalian C, and extremely rare in the Westphalian D.

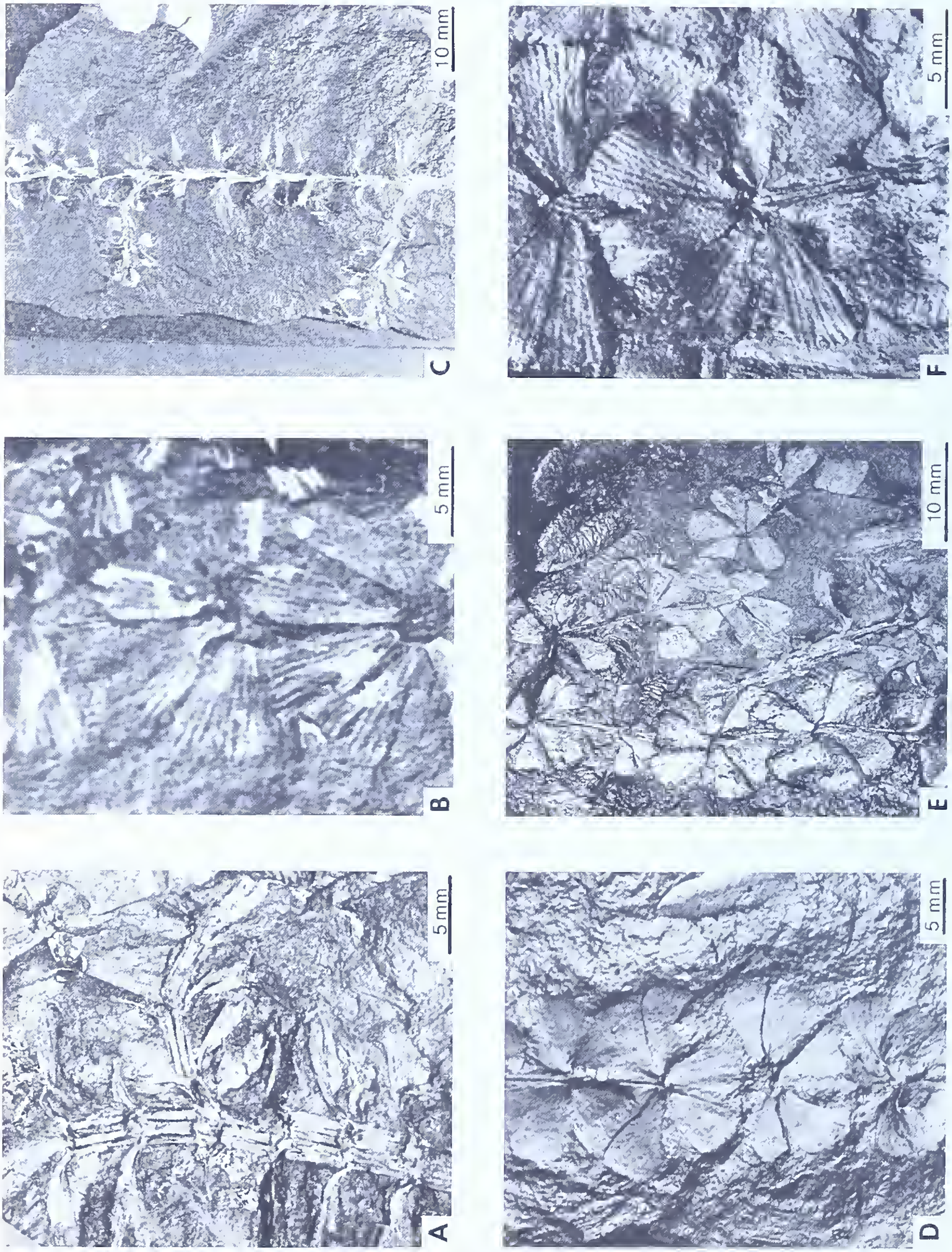
SPECIMENS: WPMM F464, F680.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenophyllum emarginatum (Brongniart) Koenig, 1825
(Figure 11C, D, E, F)

Sphenophyllum emarginatum Brongniart, 1822, p. 209, 230, 234, pl. 2, fig. 8a, b; 1828b, p. 68, 172.
Sphenophyllum emarginatum (Brongniart) Koenig, 1825, pl. 12, fig. 149.
Sphenophyllum emarginatum Brongniart. Bell, 1938, p. 89, pl. 93, figs. 1-3.
Sphenophyllum emarginatum Brongniart. Gothan and Remy, 1957, p. 59, 189, 190, fig. 50; chart 5.
Sphenophyllum emarginatum Brongniart. Abbott, 1958, p. 339, pl. 38, figs. 29, 34; pl. 44, fig. 66; pl. 45, fig. 72; chart 3.
Sphenophyllum emarginatum Brongniart. Crookall, 1969, p. 586, pl. 107, fig. 6; text-figs. 169, 171B.

DESCRIPTION: The specimens represent the young portions of the stem. They are 0.5 to 1.5 mm broad, have internodes 8 to 10 mm long, and are longitudinally ribbed; single branches arise at the slightly enlarged nodes. The leaves are wedge shaped, usually of equal length, 6 to 12 mm long and 2.5 to 9 mm wide at the apex; there are commonly six per whorl, radiating from slightly enlarged nodes. The sides of the leaves are straight to concave; the distal margin is only gently arched, and is entire but usually finely dentate and bearing 8 to 10 obtusely rounded teeth. Small leaves near the apex of the stem generally are simple and less dissected than those on the older portion of the stem, where the distal margins are usually dissected by a central cleft, 2 mm or more in depth, and two or more shorter lateral clefts. All leaves of a single whorl have the same kind of dissection. Deeply dissected leaves are wider at the distal margin and appear similar to *S. cornutum* Lesquereux. A single, thick vein enters the base of the leaf and forks three or four times into a number of equal veinlets, so that one enters each tooth, where it becomes enlarged at the distal margin and appears as a submucronate tip.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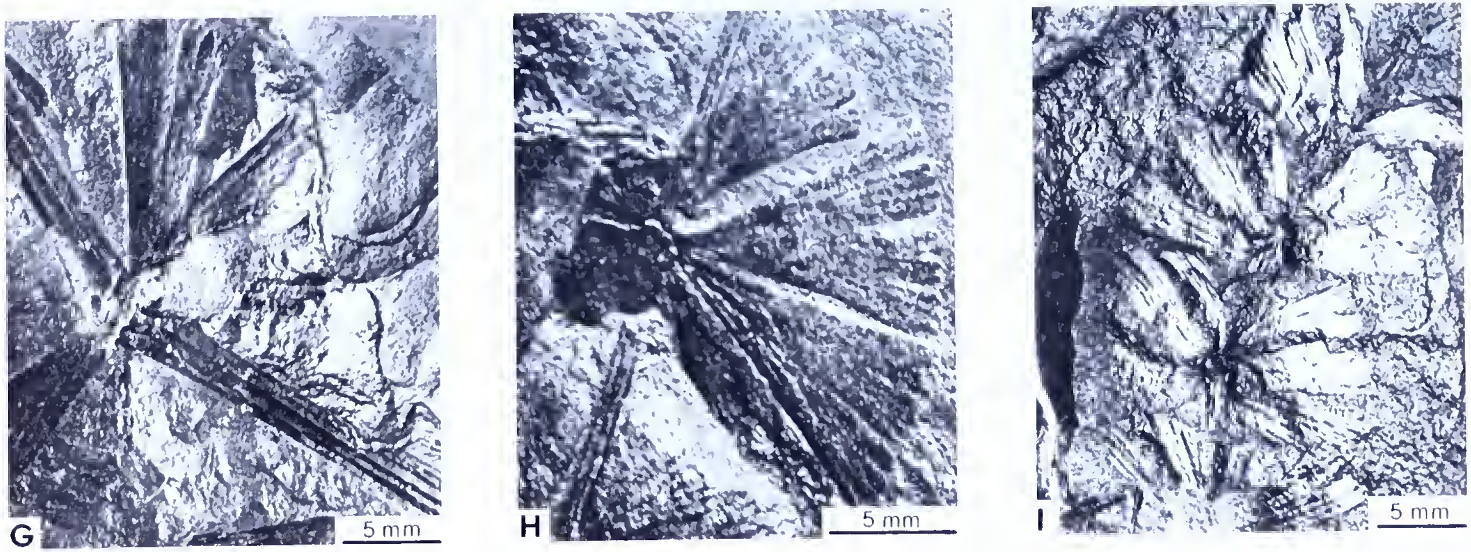


Figure 11. A, B. *Sphenophyllum cuneifolium* (Sternberg) Zeiller [WPMM F464, F680]; C, D, E, F. *Sphenophyllum emarginatum* (Brongniart) Koenig [WPMM F681, F467, F405]; G. *Sphenophyllum longifolium* (Germar) Gutbier [WPMM F611]; H. *Sphenophyllum majus* (Bronn) Bronn [WPMM F471]; I. *Sphenophyllum oblongifolium* (Germar and Kaulfuss) Unger [WPMM F678].

REMARKS: *Sphenophyllum emarginatum* has some similarity in shape to *S. verticillatum* (Schlotheim) Zeiller. The main differences between these two species are that the leaves of *S. verticillatum* are trizygoid in a verticil, heterophyllous (of unequal length), and narrowly triangular, having straight to slightly convex sides; distal margins are arched, finely turbinate, or rounded. The leaves of *S. emarginatum* are wedge shaped and usually equal in size in the same whorl; their distal margin is only gently arched and is usually nearly straight and finely dentate. The distal margins of the leaves are very often obscure when indistinctly dentate; thus it is difficult to be sure whether they were originally dentate or are imperfectly preserved.

Sphenophyllum emarginatum also resembles *S. cuneifolium* (Sternberg) Zeiller in the dissection of its leaves, which ranges from entire at the apex of the stem to deeply dissected toward the base. These two species are easily distinguished by their vegetative differences; the teeth and lobes of *S. emarginatum* are obtusely lobed, whereas those of *S. cuneifolium* are sharply pointed.

The main difference between *S. emarginatum* and *S. oblongifolium* (Germar and Kaulfuss) Unger is in the leaf arrangement; the leaves of the former species are usually of equal length, whereas the leaves of the latter have a trizygoid arrangement in each whorl.

Although some of the larger leaves of *S. emarginatum* resemble the normal leaves of *S. majus* (Bronn) Bronn in size, these two species cannot be confused with each other. The leaves of the former species are generally smaller, and *S. majus* has rounded, not pointed, teeth.

DISTRIBUTION: In North America, *Sphenophyllum emarginatum* ranges from uppermost Pottsvillian (Westphalian B_2) to lower Monongahelan (Stephanian B). This species is very rare in the uppermost Pottsvillian, abundant in the Alleghenian and lower Conemaughian, and rare in the upper Conemaughian and lower Monongahelan. It is known from the central and Appalachian regions, and from the Narragansett basin of the United States. This species is also known from the Pictou Group of New Brunswick, Canada, and the Morien (Pictou) Group (Westphalian C and D) of Nova Scotia, Canada. In Europe, the species is rare in the Westphalian B, fairly common in the Westphalian C, very common in the Westphalian D, and rare in the Stephanian A.

SPECIMENS: WPMM F681, F467, F405.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenophyllum longifolium (Germar) Gutbier, 1843

(Figure 11G)

Sphenophyllites longifolius Germar, 1837, p. 426, pl. 2, fig. 2a, b.

Sphenophyllum longifolium (Germar) Gutbier, 1843, p. 72.
Sphenophyllum longifolium Germar. Lesquereux, 1879, pl. 91, fig. 6; 1880, p. 53.
Sphenophyllum longifolium (Germar) Geinitz. Abbott, 1958, p. 347, pl. 45, figs. 70, 73; chart 3.
Sphenophyllum cf. *longifolium* (Germar) Geinitz. Oleksyshyn, 1976, p. 158, fig. 8B, C, D.

DESCRIPTION: The specimens consist of fragments of stems that have a few longitudinally striated internodes and slightly enlarged nodes from which the leaves arose. The leaves are narrow, wedge shaped, 4 to 6 in a verticil, 1.8 to 2.0 cm long, and 0.4 to 0.6 cm wide in their widest upper portion. The lateral margins of the leaves are nearly straight, and their distal margins are bluntly toothed to laciniate in the upper one third of the leaf. Only one vein enters the narrow base of the leaf, and, after some asymmetric dichotomous divisions, one such veinlet enters each tooth in the distal margin of the leaf. The internodes, 1 to 1.2 mm wide, range from 12 to 18 mm in length and are always shorter than the leaves.

REMARKS: *Sphenophyllum longifolium* is very easy to distinguish from the other species because of its long, narrow, wedge-shaped leaves.

DISTRIBUTION: In North America, this species ranges from Alleghenian to lower Dunkardian (Westphalian D to Stephanian C). It is known from the central and Appalachian regions and from the Narragansett basin in the United States. In Europe, this species ranges from the uppermost Westphalian D through the Stephanian A, B, and C.

SPECIMEN: WPMM F611.

LOCALITY: St. Clair, near Pottsville, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenophyllum majus (Bronn) Bronn, 1835
(Figure 11H)

Rotularia major Bronn, in Bischoff, 1828, p. 89, 131, pl. 13, fig. 2a, b.
Sphenophyllum majus (Bronn) Bronn, 1835, p. 32, pl. 8, fig. 9a, b.
Sphenophyllum majus Bronn. White, 1899, p. 180, pl. 50, figs. 5, 6a; pl. 51, fig. 9; pl. 73, fig. 3.
Sphenophyllum majus Bronn. Bell, 1938, p. 90, pl. 94, figs. 1, 2.
Sphenophyllum majus (Bronn) Bronn. Abbott, 1958, p. 349, pl. 37, fig. 23; pl. 46, fig. 75; chart 4.
Sphenophyllum majus Bronn. Crookall, 1969, p. 594, pl. 107, fig. 1; pl. 108, fig. 1; text-figs. 163B, 166, 171D. (Contains a more complete synonymy.)

DESCRIPTION: The stem of the figured specimen is 1.5 mm broad and slightly ribbed longitudinally; the nodes are slightly enlarged, and the internodes average 10 mm in length. The leaves are wedge shaped, 10 to 13 mm long and 6 to 8 mm broad at the distal margin; there are usually six leaves in a whorl, radiating from the node. The lateral leaf margins are commonly straight or slightly convex, parallel to the outer veinlets; the distal margin is straight to slightly arching and is crenate or irregularly toothed, so that the leaves are cut into acuminate laciniae. The central notch of the distal margin is either shallow, about 0.5 to 1 mm, or deep, to nearly one half the length of the leaf. In the leaves of the older portions of the stem, additional, more shallow incisions cut the distal margin of the leaf; the veinlets fork as many as five times before a thin veinlet enters each sharp tooth or lacinia at the distal margin.

REMARKS: This species is similar to *S. longifolium* (Germar) Geinitz. The main difference is that the leaves of the latter species are longer and narrowly cuneate in form, whereas those of *S. majus* are only about one half this length and broadly triangular in form. The stems of *S. majus* are only delicately ribbed or almost smooth, whereas those of *S. longifolium* are distinctly ribbed. *Sphenophyllum cuneifolium* (Sternberg) Zeiller has smaller leaves, six to 12 per whorl, which have shorter, pointed teeth. *Sphenophyllum majus* has larger, wedge-shaped leaves, six to nine per whorl, which usually have straight lateral margins and more numerous, blunter teeth. The leaves of *S. oblongifolium,* six per whorl, are narrowly triangular and have convex lateral margins, and the teeth of the distal margin are large and sharply pointed.

DISTRIBUTION: In North America, *Sphenophyllum majus* ranges from upper Pottsvillian (Westphalian B) to Dunkardian (Lower Permian) (Abbott, 1958, p. 349). The reports of this species in post-Alleghenian strata are questionable (Darrah, 1970, p. 177). This species is known from the central and Appalachian regions in the United States, from the Minto Formation (Pictou Group) of New Brunswick, Canada, and from the Morien (Pictou) Group of Nova Scotia, Canada. In Europe, this species is rare in the Westphalian A and B, common in the Westphalian C and D, and rare in the Stephanian A.

SPECIMEN: WPMM F471.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenophyllum oblongifolium
(Germar and Kaulfuss) Unger, 1850
(Figures 11I; 12A, B)

Rotularia oblongifolia Germar and Kaulfuss, 1831, p. 225, pl. 65, fig. 3.

Sphenophyllum oblongifolium (Germar and Kaulfuss). Unger, 1850, p. 70.

Sphenophyllum oblongifolium Germar and Kaulfuss. Bell, 1938, p. 91, pl. 94, figs. 3-7; pl. 95, figs. 1, 2.

Sphenophyllum oblongifolium (Germar and Kaulfuss) Unger. Abbott, 1958, p. 351, pl. 38, figs. 33, 37, 42, 43; pl. 44, fig. 69; pl. 47, figs. 80, 81; chart 4.

Sphenophyllum oblongifolium (Germar and Kaulfuss) Unger. Darrah, 1970, p. 179, pl. 43, figs. 1, 2, 4; pl. 44, fig. 1.

DESCRIPTION: The stem is 1.5 to 2 mm broad and is slightly enlarged at the nodes, from which the leaves arise; the internodes are 6 to 12 mm long and are longitudinally ribbed. The leaves, six in a whorl, are narrowly obovate to cuneate, and trizygoid in appearance, that is, differentiated into three bilaterally symmetrical pairs; two pairs of nearly equal length spread approximately at right angles to the stem, and the third, shorter pair is directed downward and usually deflexed. The leaves of a whorl are not evenly spaced around the node, leaving a small space opposite the shorter, usually deflexed pair. The leaves of two nearly equal pairs average 10 mm long and 3 mm broad, and the leaves of the shortest pair average 5 mm long and 2 mm broad. The lateral margins of the leaves are straight to gently convex, and widest near the middle; the distal margin is straight to slightly arching, sharply dentate, and deeply lobed in the middle. The leaves on small (young) stems are about 1.5 mm wide and often do not have a median notch and lateral clefts, whereas on larger (older) stems the leaves are more dissected by a median notch and lateral clefts, making the distal margin four-lobed. Each lobe has a few acutely pointed, submucronate teeth of varying lengths. A single vein enters the base of each leaf, immediately bifurcates twice, and bifurcates again approximately in the middle portion of the leaf, one veinlet entering each tooth of the mucronate apex.

REMARKS: The deep dissection of leaves in *Sphenophyllum oblongifolium* resembles the dissection of *S. cuneifolium* (Sternberg) Zeiller and *S. angustifolium* (Germar) Goeppert. The main difference between these species is that *S. oblongifolium* has a trizygoid leaf arrangement, whereas the other two species have leaves of equal length. The difference between *S. oblongifolium* and *S. majus* (Bronn) Bronn is that the leaves of the first species are of trizygoid habit, whereas the leaves of *S. majus* are larger and more wedge shaped, and have straight lateral margins of about equal length.

DISTRIBUTION: In North America, *Sphenophyllum oblongifolium* ranges from upper Pottsvillian (Westphalian B) to Dunkardian (Lower Permian). This species is very rare in the upper Pottsvillian and lower Alleghenian, is not common in the upper Alleghenian and lower Conemaughian, and is common from the upper Conemaughian through the Dunkardian. It is known from the central and Appalachian regions in the United States, and from the Morien (Pictou) Group (Westphalian C and D) of

Nova Scotia, Canada. In Europe, this species is known only from Stephanian and Rothliegend (Lower Permian) strata.

SPECIMENS: WPMM F678, F679, F631.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenophyllum verticillatum (Schlotheim) Zeiller, 1885
(Figure 12C, D, E)

Palmacites verticillatus Schlotheim, 1820, p. 386.
Sphenophyllum verticillatum (Schlotheim) Zeiller, 1885, p. 140, pl. 8, fig. 4.
Sphenophyllum verticillatum Schlotheim, Gothan and Remy, 1957, p. 157, fig. 156; chart 5.
Sphenophyllum verticillatum (Schlotheim) Zeiller. Abbott, 1958, p. 363, pl. 38, figs. 30, 31, 38; chart 4.

DESCRIPTION: The stems of the figured specimens are slender, flexuous, and longitudinally ribbed, about 1.5 mm thick, and bear whorls of leaves arising from enlarged nodes, separated from each other by internodes 8 to 12 mm long; the lateral branches also arise from the nodes at about 45 degrees. The leaves, arranged six in one whorl, are cuneate and are 7 to 12 mm long and 4 to 5 mm wide at the distal margin. The leaves on each node are anisophyllous (diverse in length) and are arranged in pairs. The longest pair is at the top of the whorl, the smaller, intermediate, pair is in the middle, and the shortest pair is deflexed. The leaves in the whorl are not evenly attached around the node, leaving an open space opposite the shortest, deflexed pair. The lateral margins of the leaves are straight to slightly concave, parallel to the neighboring veins, and the distal margin is rounded or slightly turbinate and has bluntly rounded teeth. The dissection of the leaves varies from obtusely dentate on small branches and near the apices of larger branches of the stem to deeply dissected on the older portion of the stem and on larger branches. The single vein, which enters the base of the leaf, dichotomizes two to five times, each veinlet ending in a tooth at the distal margin.

REMARKS: The leaves of *Sphenophyllum verticillatum* resemble those of *S. emarginatum* Brongniart in that both species have an obtusely dentate distal margin. The main difference between these two species is that *S. emarginatum* usually has six leaves of equal length, symmetrically and equally arranged around the node, whereas *S. verticillatum* has six anisophyllous leaves, arranged in three pairs of different length, unequally spaced around the node. *Sphenophyllum verticillatum* is also similar to *S. obongifolium* (Germar and Kaulfuss) Unger in the trizygoid leaf arrangement. The main difference between these two species is that the leaves of the former species have bluntly rounded teeth, whereas those of *S. oblongifolium* have sharply pointed teeth.

DISTRIBUTION: In North America, *Sphenophyllum verticillatum* ranges from lower Alleghenian (Westphalian C) to Monongahelan (Stephanian B). It is known from the central and Appalachian regions of the United States. In Europe, the species is known from the Westphalian D, Stephanian A, B, and C, and Lower Rothliegend (Lower Permian).

SPECIMEN: WPMM F638.

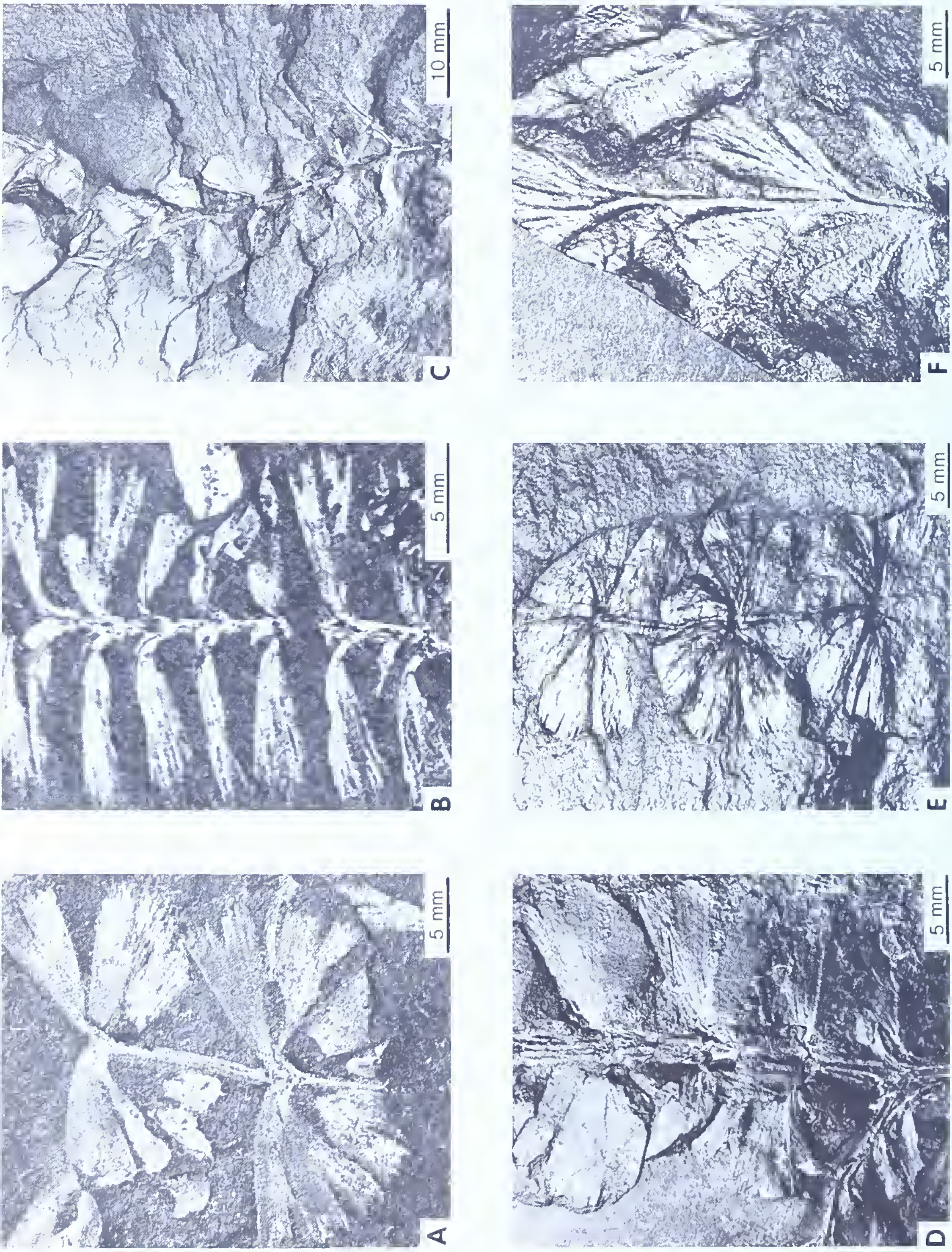
LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Subphylum PTEROPHYTA and "PTERIDOPHYLLA"
Class PTEROPSIDA
Order SPHENOPTERIDALES
Family SPHENOPTERIDACEAE
Genus *Sphenopteris* (Brongniart) Sternberg, 1825
Sphenopteris (Eremopteris) missouriensis Lesquereux, 1880
(Figure 12F)

Eremopteris missouriensis Lesquereux, 1879, pl. 53, figs. 8, 8a; 1880, p. 295.
Sphenopteris missouriensis D. White, 1899, p. 43, pl. 14, figs. 1, 2.
Sphenopteris missouriensis? (Lesquereux). Bell, 1938, p. 27, pl. 10, fig. 3; pl. 11, fig. 2.

DESCRIPTION: The figured specimen represents an ultimate pinna and a few pinnules. The pinna is linear-triangular and acute, having a thick, flexuous rachis to which the pinnules are attached. The pinnules are alternate. In the lower portion of the pinna the pinnules are palmate, deeply dissected into a few lobes, and decurrently alate; in the higher part of the pinna, the pinnules are more triangular in shape, decurrent, and divided into linear, cuneate, or truncate lobes, often shallowly bifid at the apex. Nervation is obscured, and the primary vein is decurrent, splitting near the base into a few branches, which divide again at the base of each lobe. A single veinlet enters the apex of each lobe and tooth.

REMARKS: Because of the variable shape of the pinnules depending on their position in the frond and the degree of their development, this species has been described under different specific names: *Sphenopteris spinosa* Goeppert and *Palmatopteris furcata* (Brongniart) H. Pott. *Sphenopteris (Eremopteris) missouriensis* has some similarity to *S. spiniformis* Kidston,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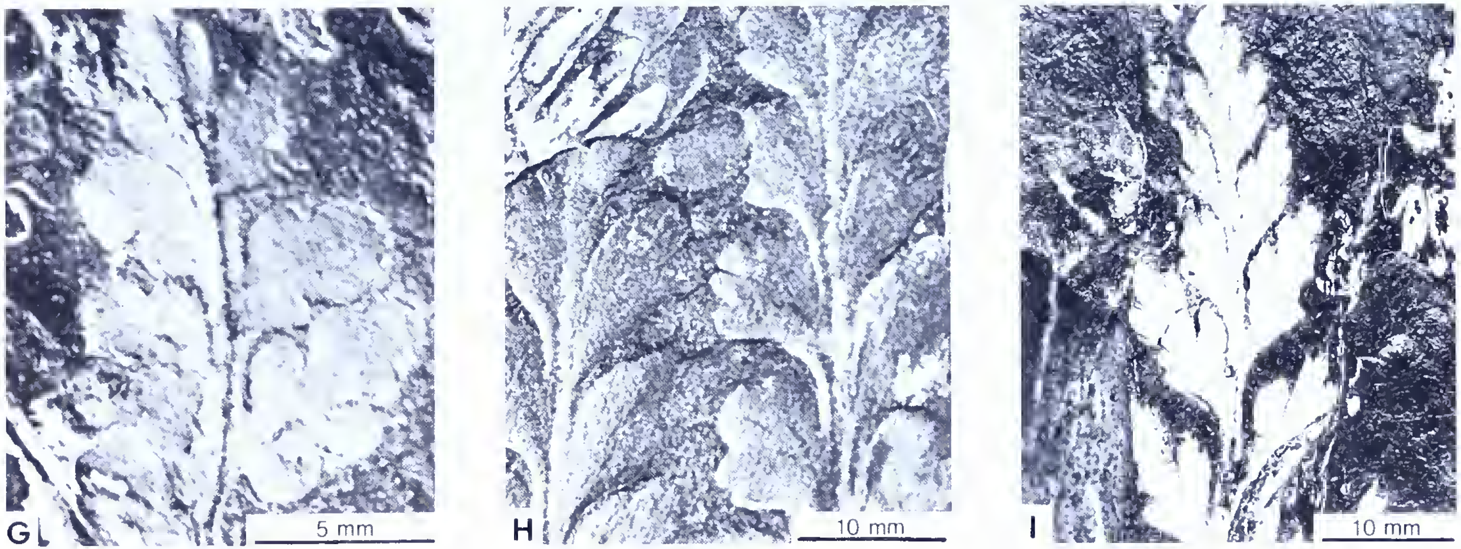


Figure 12. A, B. *Sphenophyllum oblongifolium* (Germar and Kaulfuss) Unger [WPMM F679, F631]; C, D, E. *Sphenophyllum verticillatum* (Schlotheim) Zeiller [WPMM F638]; F. *Sphenopteris (Eremopteris) missouriensis* Lesquereux [WPMM F508]; G, H. *Sphenopteris macilenta* Lindley and Hutton [WPMM F650, F635]; I. *Sphenopteris spiniformis* Kidston [WPMM F613].

but the lobes of the pinnules in the former species are only bluntly acuminate, whereas in the latter species they are sharply pointed.

DISTRIBUTION: *Sphenopteris (Eremopteris) missouriensis* is known from the Pottsvillian-Alleghenian transitional zone and from the Alleghenian (Westphalian B_2, C, and D) in the Middle and Southern Anthracite coal basins of Pennsylvania in the United States. It is also known from the Morien (Pictou) Group of the Sydney coal field in Nova Scotia, Canada.

SPECIMEN: WPMM F508.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenopteris macilenta Lindley and Hutton, 1835
(Figure 12G, H)

Sphenopteris macilenta Lindley and Hutton, 1835, p. 193, pl. 151.
Pseudopecopteris macilenta (Lindley and Hutton). Lesquereux, 1880, p. 219.
Sphenopteris macilenta Lindley and Hutton. Kidston, 1923, p. 58, pl. 9, figs. 4, 4a, 5.

DESCRIPTION: This species is represented by a few ultimate, lanceolate pinnae, which are attached slightly obliquely to the rachis. Pinnules are alternate, large, very decurrent, and contracted into a short footstalk. There are three different shapes of pinnules: on the lower pinnae, basal pinnules are subtriangular and have four to five deeply divided, rounded lobes, of which the terminal is the largest (Figure 9G); the upper pinnules on the lower pinnae are trilobate (Figure 9H); and the pinnules on the upper pinnae are either obovate, generally having three more or less prominent, rounded lobes, or elongate-oval, having two or three, more feebly developed lobes, the uppermost being oval and entire (Figure 9G). Nervation consists of a central vein arising from the rachis, from which lateral veinlets fork dichotomously several times and extend into each lobe.

REMARKS: *Sphenopteris macilenta* may be distinguished from other species of this genus by its large pinnules of different shapes found in different positions on the pinna and on the frond.

DISTRIBUTION: *Sphenopteris macilenta* is a rare species, known only from the shale of the lower portion of the Llewellyn Formation (Alleghenian; Westphalian D) in the Southern Anthracite coal basin of Pennsylvania and from Alabama in the United States. In Europe, this species is known from Radstockian strata (Westphalian D) of England, and from Westphalian D strata of the Saar Basin in West Germany.

SPECIMENS: WPMM F650, F635.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Sphenopteris spiniformis Kidston, 1893
(Figures 12I; 13A)

Sphenopteris spiniformis Kidston, 1893, p. 103.

Sphenopteris spiniformis Kidston, 1923, p. 62, pl. 13, figs. 1, 1a, 2-5; pl. 14, figs. 1, 2.

Sphenopteris spiniformis Kidston. Bell, 1938, p. 26, pl. 10, fig. 2; pl. 11, fig. 1.

Sphenopteris cf. *spinaeformis* Kidston. Darrah, 1970, p. 157, pl. 25, fig. 2.

DESCRIPTION: The specimen represents a bipinnate frond. The penultimate pinnae are long and deltoidal; the rachis of the penultimate pinnae is about 2 mm broad and alate, and has a slightly elevated central ridge and elongated apiculi. The ultimate pinnae are alternate and broadly lanceolate; they are either separated by a short space or touch each other laterally, and taper gradually upward to an acute tip. The rachis of the ultimate pinnae is straight and apiculate. The pinnules are alternate, directed forwards, deltoidal or subtriangular in shape, decurrent, and attached to the rachis by a broad footstalk. The pinnules on the basal portion of the lower pinnae have two to three truncate or slightly rounded cuneate lobes, some of which have a few sharp teeth; the apex of each of these pinnules terminates in a spine-like point. The middle pinnules of the pinna exhibit the same structure but have a wide decurrent attachment to the rachis. The upper pinnules of the pinna have only a few lobes, and are sessile and confluent; the terminal pinnule ends with a prominent spine. Nervation consists of a single central vein which enters the pinnule and dichotomizes near its base; each vein of a branch divides again into small veinlets extending to each ultimate lobe or tooth.

REMARKS: *Sphenopteris spiniformis* is related to *S. (Eremopteris) missouriensis* Lesquereux, but the segments of the pinnules of the latter species are only bluntly acuminate. *Sphenopteris spiniformis* has often been confused with *S. artemisiaefolioides* Crépin; the main difference is that the pinnule segments of the latter species are rounded at the apex and do not possess spine-like points as in *S. spiniformis*.

DISTRIBUTION: *Sphenopteris spiniformis* is known in the United States from the Alleghenian (Westphalian C and D) strata of the Mazon Creek area in Illinois and the Southern Anthracite coal basin of Pennsylvania. It is also known from the Minto and Clinton Formations (Pictou Group) (Westphalian C and D) in New Brunswick, Canada. In Europe, this species is rare in Namurian but more common in Westphalian strata.

SPECIMEN: WPMM F613.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Family EUSPHENOPTERIDACEAE

Genus *Eusphenopteris* Simpson-Scharold, 1934

Eusphenopteris neuropteroides (Boulay) Novik, 1947

(Figure 13B, C, D, E, F)

Pecopteris neuropteroides Boulay, 1876, p. 32, pl. 2, figs. 6, 6b.
Sphenopteris neuropteroides Boulay. Zeiller, 1883, p. 186.
Sphenopteris neuropteroides (Boulay) Zeiller, 1886, pl. 2, figs. 1, 2; 1888, p. 70.
Sphenopteris neuropteroides (Boulay). Bell, 1938, p. 23, pl. 5, fig. 4; pl. 6; pl. 7; pl. 8, fig. 1.
Eusphenopteris neuropteroides (Boulay) Zeiller. Novik, 1947, p. 2.
Eusphenopteris neuropteroides (Boulay) Novik. Van Amerom, 1975, p. 54, pl. 28, figs. 1-3, 5, 7; pl. 30, figs. 1-10; pl. 31, figs. 2-7; pl. 32, figs. 1-5; pl. 33, figs. 1-7; pl. 34, figs. 1-8; pl. 35, figs. 5, 6; pl. 37, fig. 4.

DESCRIPTION: The species is represented by a large frond; the rachis of the first order is coarsely striated with small transverse ridges and apiculi. The pinnae are alternate, touching or overlapping each other, and are oblong-lanceolate, attached at very open angles in the lower portion of the frond but obliquely in the higher portion; the ultimate pinnae contract abruptly at the apex into an acute point. The penultimate pinnae in the lower portion of the frond have pinnatifid pinnules; in the middle portion they have more or less lobed pinnules, and those at the base of the pinna are trilobate or bilobate. In the upper portion the pinnae have simple pinnules. Pinnae of the last order in the lower portion of the frond are attached by a thick footstalk, are upright or slightly oblique, and contain one to three pairs of confluent, ovate, or rounded-quadrate pinnules in addition to a broad terminal lobe. The form of the pinnules is variable, and depends upon their position on the frond; they may be rounded, ovate to rounded-elongate, or quadrate. The position of the pinnules on the frond also determines whether they are attached by a broad base or free, and whether they are upright or confluent and decurrent.

Nervation consists of a short central vein divided at acute angles into branches by several dichotomies; characteristically a strong branch ascends more or less parallel to the axis of a parent pinna. Small papilla-like circular elevations visible on the surface of some pinnules are probably parasitic fungi, as suggested by Schimper (1869, p. 467) and Zeiller (1883).

REMARKS: *Eusphenopteris neuropteroides* has some similarities to *E. obtusiloba* (Brongniart) Novik. The main difference between these two species is that the pinnules of the latter are rounded and never have the more or less quadrate appearance seen in the pinnules of *E. neuropteroides*. In addition, the pinnules of *E. obtusiloba* are attached to the rachis by a narrow pedicel, whereas in *E. neuropteroides* they are attached by a wide base. *Pseudopecopteris anceps* Lesquereux, *Sphenopteris squamata* Lesquereux, and *S. lesquereuxi* (Newberry) Lesquereux should be treated as synonyms of *E. neuropteroides*.

DISTRIBUTION: *Eusphenopteris neuropteroides* is known from uppermost Pottsvillian, Alleghenian, and Conemaughian strata (Westphalian B_2 through Stephanian A) in the central and Appalachian bituminous and anthracite regions of the United States, and from the Morien (Pictou) Group (Westphalian C and D) in the Sydney coal field, Nova Scotia, Canada. In Europe, this species is known from the Westphalian B, C, and D, but it is most common in the Westphalian D.

SPECIMENS: WPMM F616, F718.

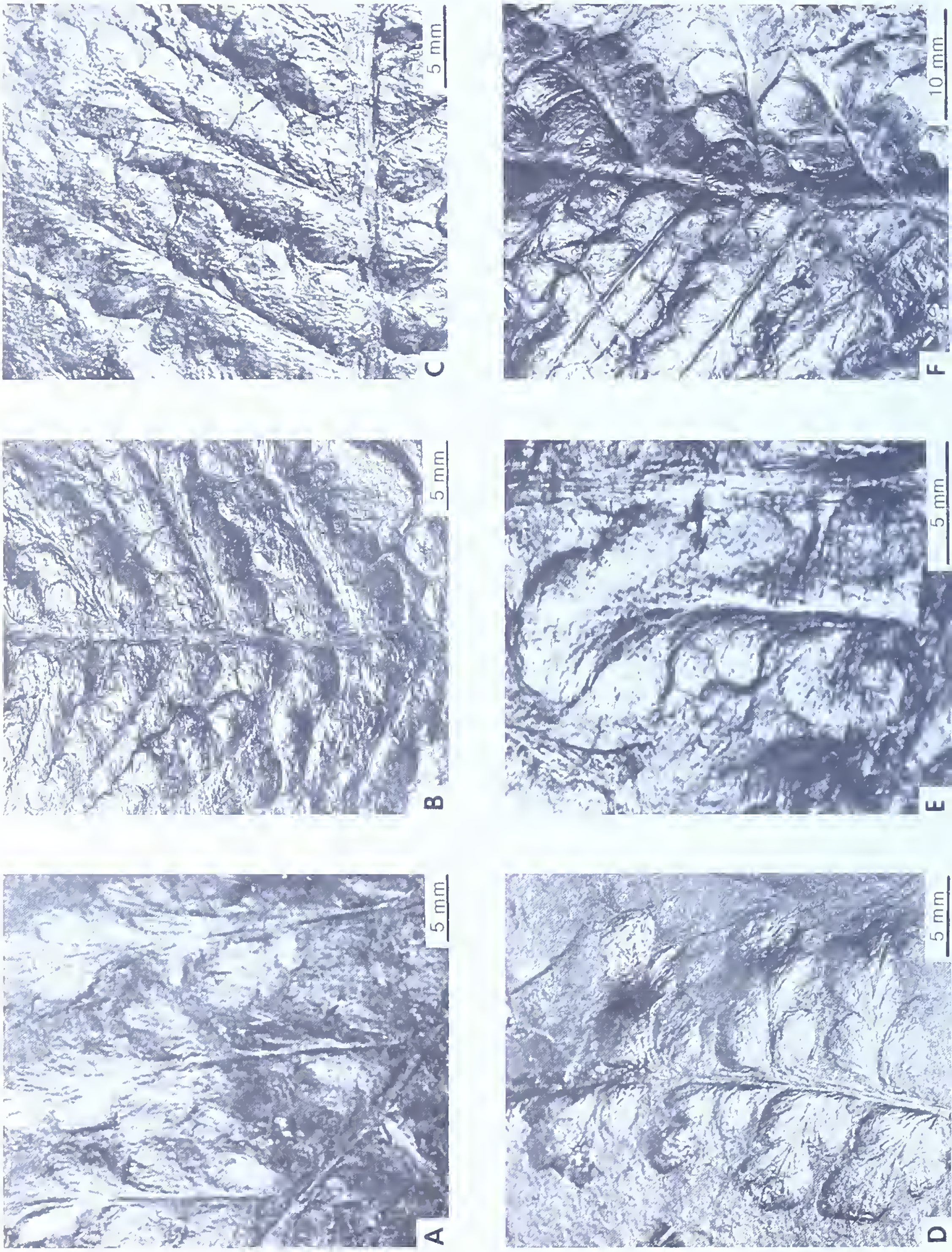
LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Eusphenopteris obtusiloba (Brongniart) Novik, 1947
(Figure 13G)

Sphenopteris obtusiloba Brongniart, 1828a, p. 204, pl. 53, fig. 2.
Sphenopteris obtusiloba Brongniart. Zeiller, 1886, pl. 3, figs. 1-4; pl. 4, fig. 1; pl. 5, figs. 1, 2; 1888, p. 65.
Pseudopecopteris obtusiloba (Brongniart) Lesquereux. White, 1899, p. 24, pl. 7, figs. 1-3; pl. 8.
Eusphenopteris obtusiloba (Brongniart). Novik, 1947, p. 279.
Eusphenopteris obtusiloba (Brongniart) Novik. Van Amerom, 1975, p. 31, pl. 6; pl. 7, figs. 1-8; pl. 8; pl. 10, figs. 1-4, 7, 8; pl. 12, fig. 8; pl. 15, figs. 6, 11.

DESCRIPTION: This species is represented by a few fragments of tertiary pinna bearing a few lobed pinnules attached to a straight rachis that has fine longitudinal striations. The pinnules on the lower portion of the pinna are alternate and oblong-lanceolate, touch each other on their margins, and are divided into three to five deeply cut, rounded lobes. The middle pinnules are oblong-oval and have less prominent lobes, and the uppermost pinnules are rounded and entire.

The nervation is distinct. In the lobed pinnules, branches to each lobe arise at acute angles from the central vein; these branches bifurcate two or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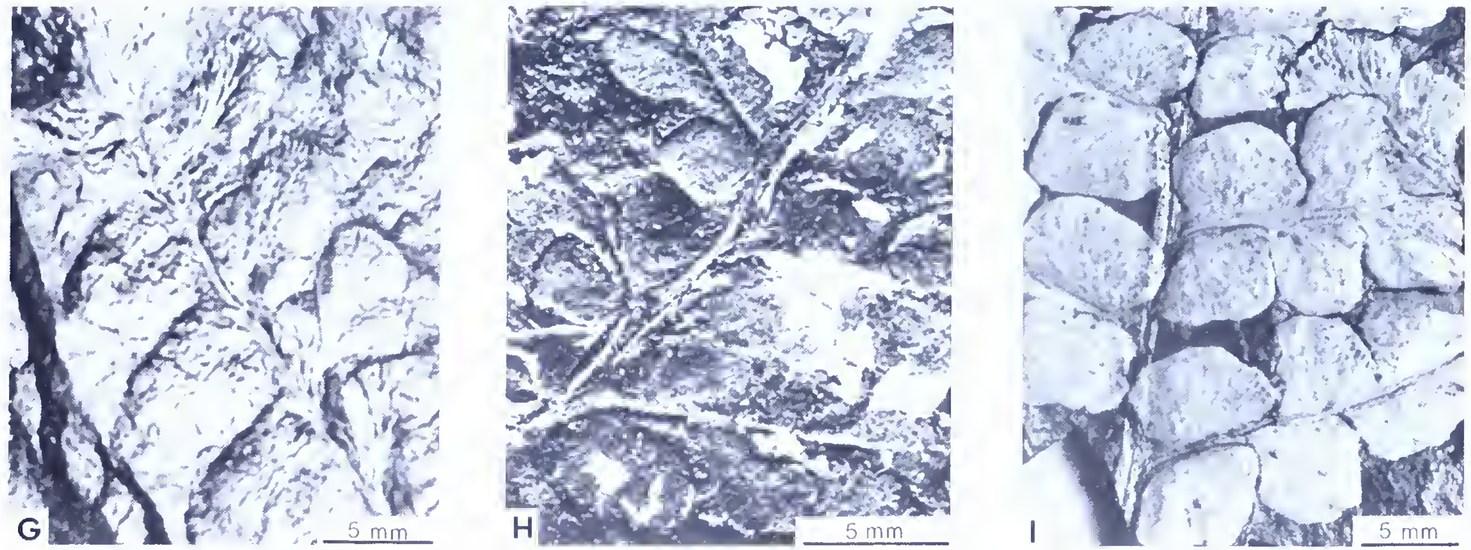


Figure 13. A. *Sphenopteris spiniformis* Kidston [WPMM F613]; B, C, D, E, F. *Eusphenopteris neuropteroides* (Boulay) Novik [WPMM F616, F718]; G. *Eusphenopteris obtusiloba* (Brongniart) Novik [WPMM F688]; H. *Eusphenopteris nummularia* (Gutbier) Novik forma *nummularia* Van Amerom [WPMM F705]; I. *Mariopteris* cf. *inflata* D. White [WPMM F510].

three times to form numerous veinlets passing to the segments of the pinnule. In small, more orbicular pinnules the central vein is not evident and the veinlets radiate from the base of the pinnule.

REMARKS: *Eusphenopteris obtusiloba* is easily distinguished from *E. neuropteroides* (Boulay) Novik by the rounded form of its pinnules, which never have the more or less quadrate appearance characteristic of the pinnule segments of *E. neuropteroides*. It is also distinguished by the narrow stalk by which the pinnules are attached to the rachis; the pinnules of *E. neuropteroides* are attached to the rachis by a wide base. In the opinion of Kidston (1923, p. 31), *Eusphenopteris striata* (Gothan) Novik should be considered as a synonym of *E. obtusiloba* on the assumption that the striate epidermis of the former is the result of preservation and is not due to real differences in structure between these two species.

DISTRIBUTION: *Eusphenopteris obtusiloba* is known from upper Pottsvillian and Alleghenian strata (Westphalian B, C, and D) in the central and Appalachian bituminous and anthracite regions of the United States and from the Cumberland Group (Westphalian B) in the Springhill coal field of Nova Scotia, Canada. In Europe, this species has a wide vertical range from Namurian C to Westphalian D, and also a wide geographical distribution from England and Spain on the west to the Donetz basin, Ukraine, on the east.

SPECIMEN: WPMM F688.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Eusphenopteris nummularia (Gutbier) Novik forma *nummularia* Van Amerom, 1975
(Figure 13H)

Sphenopteris nummularia Gutbier, 1835, p. 43, pl. 4, fig. 5; pl. 10, figs. 7, 8; pl. 11, fig. 3.

Sphenopteris nummularia Gutbier. Kidston, 1923, p. 38, pl. 4, figs. 1, 1a, 2, 3, 3a; pl. 5, figs. 4, 4a; pl. 7, figs. 2, 2a, 3, 3a, 4, 4a.

Eusphenopteris nummularia (Gutbier). Novik, 1947, p. 279.

Eusphenopteris nummularia (Gutbier) Novik, 1954, p. 81, pl. 18, fig. 10; chart II.

Eusphenopteris nummularia (Gutbier) Novik forma *nummularia* Van Amerom, 1975, p. 66, pl. 38, figs. 1, 2, 4, 5; pl. 39, figs. 1, 2, 3; pl. 11, fig. 7; pl. 41, figs. 4, 5; pl. 62, figs. 1, 2, 3.

DESCRIPTION: The specimens represent fragments of fronds that have short, oblong, alternate pinnae, and very oblique to slightly undulating rachises. The pinnules are generally slightly convex, oval, entire, and attached to the rachis by a thick decurrent footstalk. Some pinnules at the base of the lower ultimate pinnae are tri- or bifid, but in the higher position of the frond they are oval, entire, and slightly obtuse. Venation is obscure.

REMARKS: The tri- or bilobate form of some pinnules of the lower ultimate pinnae of *E. nummularia* resembles the pinnules of *E. obtusiloba* (Brongniart) Novik and *E. trifoliata* (Artis) Novik. In the latter two species, pinnules on the lower position of the pinnae are more lobed than those on the higher position of the frond. The main difference between *S. nummularia* and *E. obtusiloba* is that the former has smaller pinnules and is of more slender habit.

DISTRIBUTION: *Eusphenopteris nummularia* is a rare species in the United States. It occurs in Alleghenian strata (Westphalian D) in Missouri, and has now been found by the author in the shale below the Buck Mountain (No. 5) coal bed in the lower part of the Llewellyn Formation (Westphalian D) in the Southern Anthracite coal basin of Pennsylvania. In Europe, this species is known from the Westphalian A, B, C, and D of western Europe and from the Westphalian A, B, and C in the Donetz basin, Ukraine.

SPECIMEN: WPMM F705.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Group DIPLOTHMEMEAE Gothan
Family MARIOPTERIDACEAE
Genus *Mariopteris* Zeiller, 1879
Mariopteris cf. *inflata* D. White, 1943
(Figure 131)

Mariopteris inflata D. White, 1943, p. 88, pl. 18, fig. 4; pl. 19, figs. 1-4.

DESCRIPTION: The figured specimen shows a portion of the ultimate pinna and a strong, narrowly alate rachis to which a few pinnules are attached. The pinnules are lobate, alternate, slightly oblique to the rachis, and closely spaced; some slightly overlap each other along their margins. The lowest lobes of the pinnule are broadly reniform-rhomboidal and broadly attached to the rachis, the higher lobes are decurrent and have oblique distal sinuses, and the highest lobes are more or less apiculate.

Nervation is distinct; the median vein is strong, decurrent at the base, slightly flexuous, and deeply depressed in the lower portion, diminishing upward and extending nearly to the apex of the pinnule. Lateral veinlets arise from the median vein at a moderate angle and divide two or three times, and each of the distal veinlets arches strongly from the division and reaches the margin of the lobe.

REMARKS: *Mariopteris inflata* has some similarity to *M. lobata* D. White, but differs in the shape of the pinnules. The pinnules of *M. inflata* are more or less rhomboidal and have subpedicellate bases, whereas the pinnules of *M. lobata* are more rounded.

DISTRIBUTION: *Mariopteris inflata* is known from Pottsville strata, Sewell coal bed (Lower Westphalian A) of West Virginia, and the Llewellyn Formation, Buck Mountain (No. 5) coal bed (Westphalian D) in the Southern Anthracite coal basin of Pennsylvania.

SPECIMEN: WPMM F510.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Mariopteris cf. *lobata* D. White, 1943
(Figure 14A, B)

Mariopteris lobata D. White, 1943, p. 87, pl. 14, fig. 7; pl. 15, figs. 1, 2.

DESCRIPTION: The specimens represent fronds having many lanceolate, slightly acute or narrowly obtuse pinnae alternately and obliquely attached to a flexuous, narrowly alate rachis. The pinnules near the apex of each pinna are ovate, cuneate, oblique, broadly attached, decurrent, and slightly constricted on the primal side of the base. Pinnules near the base of the pinna are larger, becoming round-trilobate, elongate, and pinnatifid in about five or six lobes; the lowest lobe is rounded, the next is ovate, the upper ones are connate and shallowly sublobate, and the terminal lobe is ovate and much larger. Venation is not well preserved.

REMARKS: *Mariopteris lobata* has some resemblance to *M. pottsvillea* D. White, but differs in the greater degree of subdivisions or lobation of the pinnules. The uppermost pinnules of *M. lobata* are ovate, cuneate, and confluent, whereas in *M. pottsvillea* the uppermost pinnules are rounded but blend into the long terminal pinnule, which has a rolled margin, making its shape acute.

DISTRIBUTION: *Mariopteris lobata* is known from Pottsvillian and Alleghenian strata (Westphalian A, B, C, and D) in the Appalachian bituminous and anthracite coal regions of the United States.

SPECIMENS: WPMM F511, F704.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Mariopteris nervosa (Brongniart) Zeiller, 1880
(Figure 14C, D, E)

Pecopteris nervosa Brongniart, 1828a, p. 297, pl. 94; pl. 95, figs. 1, 2; 1828b, p. 57, 170.

Mariopteris nervosa (Brongniart) Zeiller, 1880, p. 69, pl. 167, figs. 1-4.

Mariopteris nervosa Brongniart. Kidston, 1925, p. 601, pl. 138, figs. 3, 4; pl. 140, fig. 1; pl. 143, figs. 1, 2; pl. 144, figs. 1, 4-6; pl. 153, figs. 1-7; text-figs. 88, 89. (Contains a more complete synonymy.)

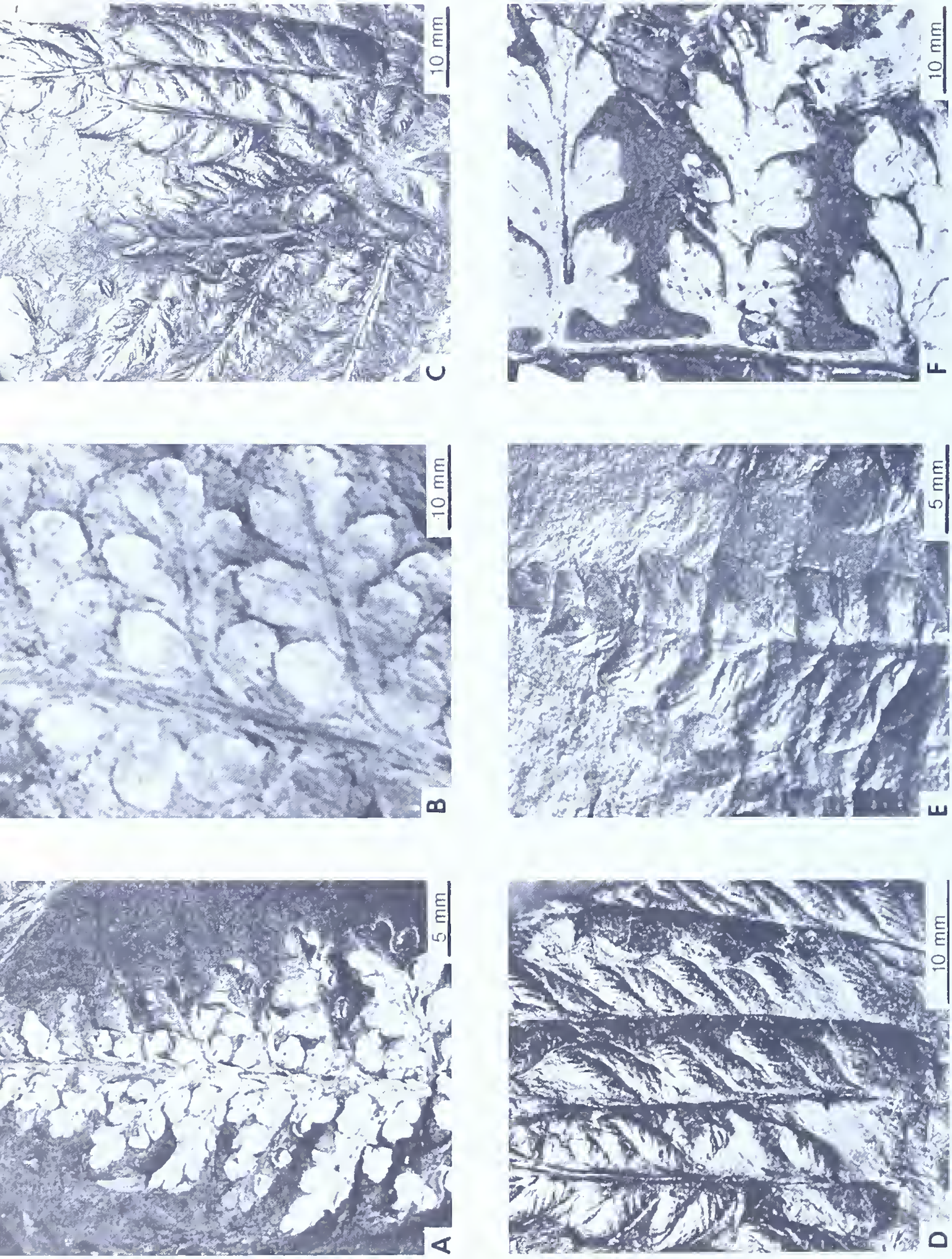
Mariopteris nervosa (Brongniart). Bell, 1938, p. 49, pl. 39, fig. 1; pl. 40, fig. 1.

Mariopteris nervosa (Brongniart). Lyons and Darrah, 1978, p. 437, fig. 3K.

DESCRIPTION: The primary pinnae in the figured specimens are alternate, broadly lanceolate, and more or less oblique to the straight or slightly flexuous, very finely, longitudinally striated rachis, bearing short transversely elongated bars on its outer surface. The pinnules are large and subtriangular, and have slightly convex or straight sides within curved margins; they are alternate, oblique to the rachis, decurrent, and either almost united to each other or free at the base of the pinnae. The apex of each pinnule is either acute or blunt and rounded. The basal ovoid pinnules often possess one or two small lobes on their distal margin, whereas the other, subtriangular pinnules are entire or are only feebly crenulated. Small granules on the surface of the pinnules indicate the places where granular hairs were attached. The nervation is coarse. The median vein in the basal pinnules is straight; in the upper pinnules it is more or less decurrent and undulating, and extends to near the apex, where it divides into two arms. The lateral veinlets arise at an acute angle and dichotomize near their base; toward the margin, one of the veinlets frequently divides again.

REMARKS: *Mariopteris nervosa* is distinguished from *M. muricata* Schlotheim by its generally subtriangular, more joined pinnules, and the more decurrent form of the pinnules in the upper portion of the pinna. *Mariopteris nervosa* may easily be confused with *M. hirta* Stur; the main difference between these two species is that the pinnules of the latter species are larger and broader in proportion to their length, and their side margins are straighter and contract more gradually to a blunt apex.

DISTRIBUTION: *Mariopteris nervosa* is known from upper Pottsvillian (Westphalian B) to lower Conemaughian (Westphalian D) strata, but is most common in the Alleghenian and the lower portion of the Llewellyn Formation (lower Westphalian D). It is known from the anthracite coal basins of Pennsylvania, especially from the Northern Anthracite coal basin, from the bituminous coal basins of the Appalachian and central regions of the United States, and from the Morien (Pictou) Group in the Sydney coal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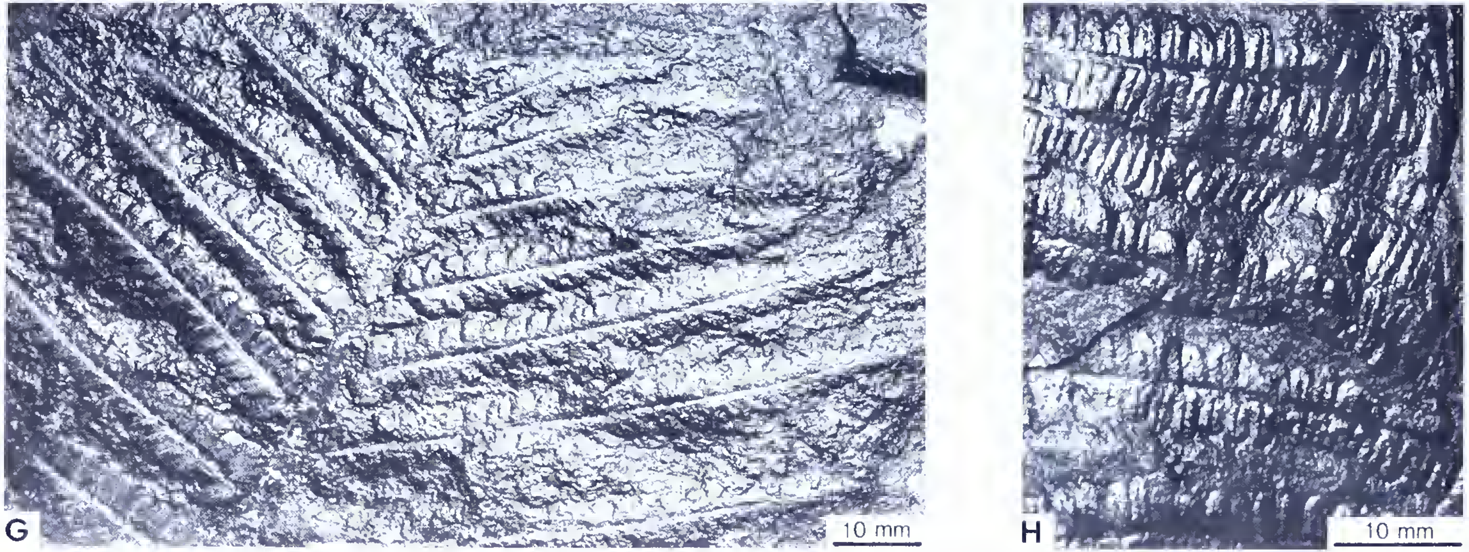


Figure 14. A, B. *Mariopteris* cf. *lobata* D. White [WPMM F511, F704]; C, D, E. *Mariopteris nervosa* (Brongniart) Zeiller [WPMM F627, F512]; F. *Diplothmema cheathami* (Lesquereux) D. White [WPMM F703]; G, H. *Pecopteris arborescens* (Schlotheim) Sternberg [WPMM F614, F513].

field in Nova Scotia, Canada. In Europe, this species is known from the entire Westphalian.

SPECIMENS: WPMM F512, F627.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus *Diplothmema* Stur

Diplothmema cheathami (Lesquereux) D. White, 1943

(Figure 14F)

Eremopteris cheathami Lesquereux, 1884, p. 770, pl. 104, figs. 2-4.
Diplothmema cheathami (Lesquereux). D. White, 1943, p. 95, pl. 28, figs. 1-3, 5-10.

DESCRIPTION: Specimens consist of fragments of fronds that have penultimate pinnae alternately attached nearly at right angles to a strong, slightly flexuous, longitudinally canaliculate rachis. The pinnae are lanceolate, and subacute at the apices. The pinnules are relatively large, brevipedicellate, alternate, open below, oblique above, and close to each other. The lower pinnules are broadly cuneate, obliquely truncate, and distally denticulate; they have a narrow, oblique basal attachment. The higher pinnules are more deeply dissected and broadly cuneate, and their lateral margins are usually slightly convex or nearly straight. Near the apex of the pinna the middle lobe of the pinnules is slightly concave and has a truncate top.

Venation is poorly preserved; the primary vein originates from the rachis of the pinna at a very acute angle, curving and forking, mostly in the lower half of the pinnule, into several veinlets that pass into the distal teeth of the pinnule.

REMARKS: *Diplothmema cheathami* has some similarity to *D. glenii* D. White, but the pinnules of the latter are usually smaller and closer to each other.

DISTRIBUTION: *Diplothmema cheathami* is known from the Kanawha Series (upper Pottsvillian; Westphalian B) in Alabama and Tennessee and from the lower portion of the Llewellyn Formation (Alleghenian; lower Westphalian D) in the Southern Anthracite coal basin of Pennsylvania.

SPECIMEN: WPMM F703.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Order PECOPTERIDALES
Family PECOPTERIDACEAE
Genus *Pecopteris* (Brongniart) Sternberg, 1825
Pecopteris arborescens (Schlotheim) Sternberg, 1825
(Figure 14G, H)

Filicites arborescens Schlotheim, 1820, p. 404.
Pecopteris arborescens (Schlotheim). Sternberg, 1825, p. 18.
Pecopteris arborescens (Schlotheim). Brongniart, 1828a, p. 310, pl. 102, figs. 1, 2; pl. 103, figs. 2, 3; 1828b, p. 56, 169.
Pecopteris arborescens (Schlotheim). Lesquereux, 1879, pl. 41, figs. 6, 7, 7a, 7b; 1880, p. 230.
Asterotheca arborescens Schlotheim. Kidston, 1924, p. 483, pl. 114, fig. 1.
Pecopteris arborescens Schlotheim. Gothan and Remy, 1957, p. 114, 161, 190, 212, fig. 161; chart 5.
Pecopteris arborescens (Schlotheim). Lyons and Darrah, 1978, p. 437, fig. 3A.

DESCRIPTION: The species is represented by a large frond having a broad, straight, smooth or finely apiculate rachis to which linear-lanceolate pinnae are alternately and obliquely attached. The pinnae are either free or touch at their margins; they are of almost equal width for the greater part of their length, and are contracted at the apex into a blunt point. The pinnules are small, usually 4 mm in length and 1-3/4 mm in width, and slightly convex; they have parallel sides and bluntly rounded apices, are alternate, and are attached to the rachis at right angles or slightly obliquely by the whole base, usually touching, but not overlapping each other. The surface of the pinnules is usually smooth, but occasionally villous. The median vein is straight and extends to the apex; lateral veinlets are simple and gently ascend to the margin.

REMARKS: *Pecopteris arborescens* has some similarity in general outline of frond to *P. cyathea* (Schlotheim) Brongniart, with which it has often been confused. In *P. cyathea* the pinnae terminate bluntly, and the pinnules on the same pinna are of unequal length; the lateral veinlets on the same pinnule are simple, but the other veinlets are bifurcated once near their bases or at some distance above, and they intermingle with the simple veinlets. In *P. arborescens* the pinnae terminate more acutely, the pinnules on the same pinna are of equal length, and the lateral veinlets are simple and undivided.

DISTRIBUTION: In the central and Appalachian regions of the United States, *P. arborescens* occurs in middle Alleghenian to early Dunkardian

(Westphalian D and Stephanian A, B, and C) strata, but is most common in the Conemaughian and Monongahelan and their equivalents. In Europe, this species occurs in the Westphalian C and D, Stephanian A, B, and C, and Lower Rothliegend Series (Lower Permian).

SPECIMENS: WPMM F513, F614.

LOCALITIES: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed; and Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris cf. *bucklandii* Brongniart, 1828a
(Figure 15A)

Pecopteris bucklandii Brongniart, 1828a, p. 319, pl. 99, fig. 2; 1828b, p. 56, 169.

Eupecopteris bucklandi Brongniart. Kidston, 1925, p. 555, pl. 120, figs. 6, 6a; pl. 132, figs. 1, 1a, 1b, 2; text-figs. 72, 73.

Eupecopteris bucklandii (Brongniart) Kidston. Novik, 1954, p. 22, pl. 2, fig. 8; charts I, II.

Pecopteris bucklandi (Brongniart). Darrah, 1970, p. 128.

DESCRIPTION: The figured specimen represents a fragment of a pinna having a few pinnules attached to a straight, longitudinally striated rachis, which bears small, scattered apiculi. The pinnules are alternate, free, oblique to the rachis, and oblong with nearly parallel sides; they terminate in an obtuse apex, are contracted at the base or decurrent on the posterior margin, and have a sinus on the anterior margin. Only some of the pinnules near the apex are slightly united to each other at the base.

Nervation consists of a thick, straight, median vein, slightly decurrent at the base and extending to the summit of the pinnule. Lateral veinlets are distant; they arise from the midvein at an acute angle and divide into two branches near their bases. Some of the veinlets in the upper branch frequently divide again, curving slightly down toward the margin of the pinnule.

REMARKS: *Pecopteris bucklandii* has similarities to *P. oreopteridis* (Schlotheim) Sternberg and *P. cistii* Brongniart. The main differences between *P. bucklandii* and *P. oreopteridis* are (1) the pinnules of the latter are not contracted at the base, but are attached to the rachis by their whole width, and are shorter in proportion to their breadth, and (2) the veinlets of the latter curve toward the margins, usually forking only once near their bases. The main differences between *P. bucklandii* and *P. cistii* are (1) the latter has not only shorter, broader, and more obtuse pinnules, but the angle of divergence of the veinlets is intermediate to that of the other two species, and (2) in the latter species, all lateral veinlets, except the upper pairs near the top, divide twice.

DISTRIBUTION: *Pecopteris bucklandii* is a rare species, known from Alleghenian, Conemaughian, and lower Monongahelan (Westphalian D and Stephanian A and B) strata in the central and Appalachian regions of the United States. In Europe, this species is rare in the Westphalian D, but more common in the Stephanian A, B, and C.

SPECIMEN: WPMM F514.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris candolliana Brongniart, 1828a
(Figure 15B)

Pecopteris candolliani Brongniart, 1828a, p. 305, pl. 100, fig. 1; 1828b, p. 56, 169.

Asterotheca candolleana Brongniart. Kidston, 1924, p. 492, pl. 116, figs. 1, 2; text-fig. 50. (Contains a more complete synonymy.)

Asterotheca candolleana (Brongniart) Zeiller. Novik, 1954, p. 18, pl. 2, fig. 5; charts I, II.

Pecopteris candolleana Brongniart. Gothan and Remy, 1957, p. 163, 190, 212, figs. 164, 206; chart 5.

Pecopteris candolleana Brongniart. Darrah, 1970, p. 113.

DESCRIPTION: The illustrated specimen preserves a few secondary linear pinnae, which are widest in the middle and contracted into an obtuse point. The pinnules are about four times longer than broad, alternate, perpendicular or slightly oblique to the longitudinally finely striated rachis, and slightly arcuate; the sides of the pinnules are parallel, except at the base, where they are contracted. Some pinnules on the same pinna are slightly shorter than others.

The venation is distinct; the median vein is thick and straight, and extends to the apex of the pinnule. Lateral veinlets arise at a wide angle and dichotomize a short distance above their base into two veins, curving toward the margin of the pinnule.

REMARKS: In strict adherence to the law of priority and the orthography given by Brongniart (1828a, p. 305; 1828b), the spelling *P. candolliana* should be used. Very close to this species is *P. lepidorachis* Brongniart, but the latter has an apiculate rachis and the pinnules are never contracted at their bases. *Pecopteris candolliana*, which has long, narrow pinnules, has some resemblance to *P. hemitelioides* Brongniart, but in the latter all lateral veinlets are simple and undivided, and the rachis of the pinna is scaly.

DISTRIBUTION: *Pecopteris candolliana* is rare in the middle Alleghenian (Westphalian D), but more common in the upper Alleghenian, Conemaughian, Monongahelan, and lower Dunkardian (Westphalian D and Stephanian) in the central and Appalachian regions and the Narragansett basin of the United States. In Europe, this species is known from the Westphalian D, Stephanian A, B, and C, and Rothliegend (Lower Permian).

SPECIMEN: WPMM F515.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris cistii Brongniart, 1828a
(Figure 15C, D, E)

Pecopteris cistii Brongniart, 1828a, p. 330, pl. 106, figs. 1, 2.
Pecopteris cistii Brongniart. Lesquereux, 1879, pl. 41, fig. 4; 1880, p. 243.
Pecopteris cistii (Brongniart). Darrah, 1970, p. 129.

DESCRIPTION: Specimens are represented by secondary, linear-lanceolate pinnae, some reaching 11 cm in length and 1.2 cm in width near the base, slightly wider above the middle and gradually tapering toward the apex; the rachis of the pinna is strong and flexuous. The pinnules are alternate, free, oblong with broadly rounded apices, and attached more or less obliquely to the rachis by a broad base; some are slightly joined to each other and decurrent. The median vein is thick and straight and extends nearly to the apex, where it forks twice; lateral veinlets arise at an acute angle, divide once near their base, and usually both divide again. In confluent pinnules near the top of the pinnae, the lateral veinlets are undivided.

REMARKS: The fronds of this species must have been very large, as is indicated not only by the form of the pinnae, but also by the different size of the pinnules on different parts of the pinnae. *Pecopteris cistii* resembles *P. polymorpha* Brongniart in the form of its pinnules, but the nervation is more distant and pursues a more ascending course to the margin, especially in the more elongated pinnules.

DISTRIBUTION: *Pecopteris cistii* is known from uppermost Alleghenian, Conemaughian, and Monongahelan (Westphalian D and Stephanian) strata in the bituminous and anthracite coal regions of Pennsylvania and contemporaneous deposits of Kansas and Texas in the United States. In Europe, this species is known from the Westphalian D and Stephanian A, B, and C.

SPECIMENS: WPMM F658, F687.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris cyathea (Schlotheim) Brongniart, 1828a
(Figure 15F, G)

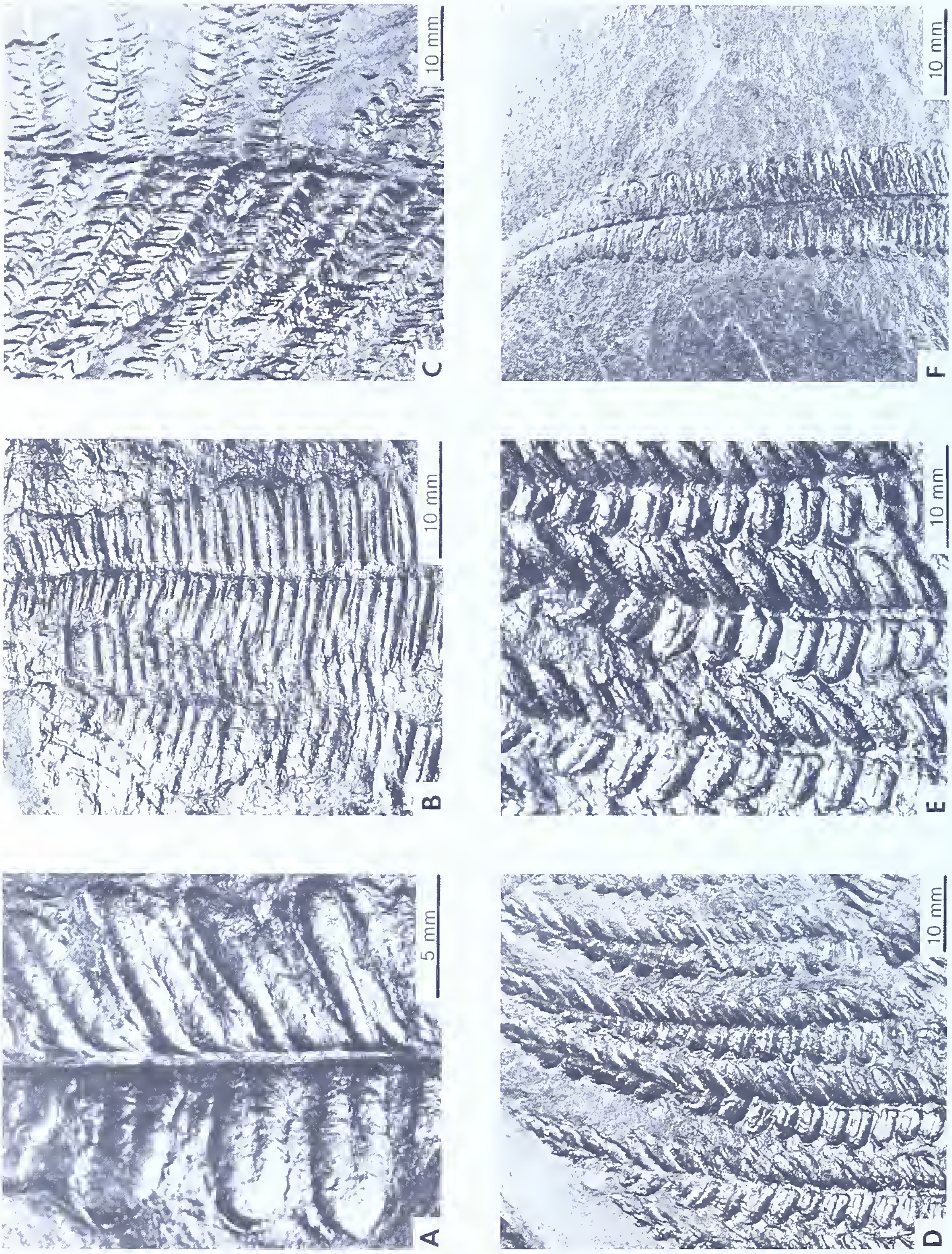
Filicites cyatheus Schlotheim, 1804, p. 403, pl. 7, fig. 11.
Pecopteris cyathea Brongniart, 1828a, p. 307, pl. 101, figs. 1-4; 1828b, p. 56, 169.
Asterotheca cyathea Schlotheim. Kidston, 1924, p. 488, pl. 114, figs. 2, 2a, 2b, 3; pl. 115, figs. 1, 1a, 1b; pl. 116, figs. 3, 3a, 3b, 4; pl. 117, figs. 3, 3a; text-fig. 49. (Contains a more complete synonymy.)
Eupecopteris (Asterotheca) cyathea (Schlotheim). Bell, 1938, p. 75, pl. 76, fig. 2.
Pecopteris cyathea Schlotheim. Gothan and Remy, 1957, p. 161, 210, figs. 162, 211; chart 5.

DESCRIPTION: The specimens show separate ultimate linear-lanceolate pinnae, about 10 cm in length and 13 mm in width for about two thirds of their length, slightly narrower at their bases and gradually contracting near their apices, where there is an abrupt contraction to an obtuse point. The pinnules are alternate; each is attached by its whole base to a straight, smooth rachis or to one marked with faint, irregular, longitudinal striae. The pinnules are contiguous, free or united to each other at their bases, oblong, usually from two to three times as long as broad, and frequently of unequal length on the same pinna; some pinnules are slightly contracted at their bases.

Nervation consists of a straight midvein extending to the apex of the pinnule, in some pinnules terminating in a dichotomy. Lateral veinlets are slightly ascending; they are either simple or divide once near their base or at some distance above it.

REMARKS: *Pecopteris cyathea* is often confused with *P. arborescens* (Schlotheim) Sternberg. The main difference between these two species is that the pinnules of *P. cyathea* are usually about three times or more longer than they are broad and frequently of unequal size on the same pinna, and some lateral veinlets bifurcate once near their base or at some distance above it and intermingle with simple, undivided veins; the pinnules of *P. arborescens,* on the other hand, gradually contract into a blunt point, and all lateral veinlets are simple and undivided. The rachis of *P. cyathea* is smooth or marked with faint, irregular, longitudinal striae, whereas the rachis of *P. arborescens* may also be smooth or bear slightly vertical, elongated apiculi.

DISTRIBUTION: *Pecopteris cyathea* is rare in Alleghenian (Westphalian C and lower D) strata, but is more common in Conemaughian, Monongahelan, and Dunkardian (uppermost Westphalian D and Stephanian A, B, and C), and Lower Permian strata. It is known from the central and Appalachian regions of the United States. In Europe, this species is known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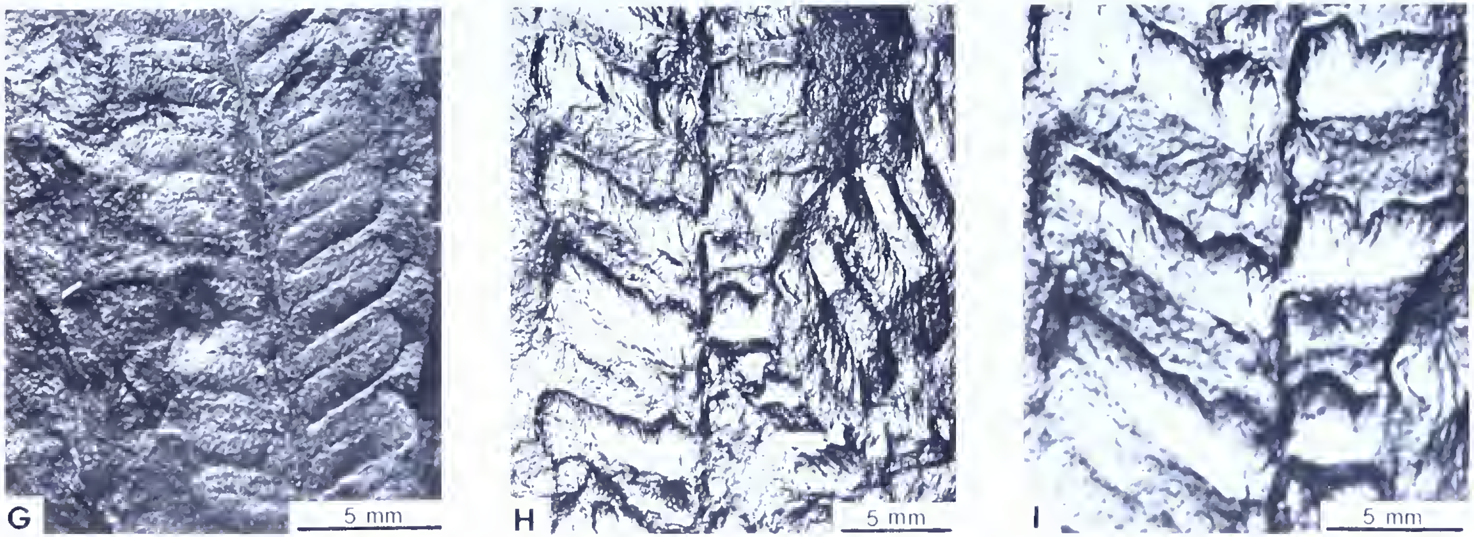


Figure 15. A. *Pecopteris* cf. *bucklandii* Brongniart [WPMM F514]; B. *Pecopteris candolliana* Brongniart [WPMM F515]; C, D, E. *Pecopteris cistii* Brongniart [WPMM F658, F687]; F, G. *Pecopteris cyathea* (Schlotheim) Brongniart [WPMM F521, F523]; H, I. *Eupecopteris fletti* Kidston [WPMM F684].

from the upper Westphalian D, Stephanian A, B, and C, and Rothliegend (Lower Permian).

SPECIMENS: WPMM F521, F523.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Eupecopteris fletti Kidston, 1925
(Figures 15H, I; 16A, B)

Eupecopteris fletti Kidston, 1925, p. 564, pl. 125, figs. 2, 2a; pl. 133; pl. 134, figs. 1, 1a, 1b; text-fig. 76.
Eupecopteris fletti Kidston. Hirmer, 1927, p. 583.

DESCRIPTION: The specimens consist of lanceolate secondary pinnae tapering to their apices; the rachis of each pinna is strong, undulate, and densely apiculate. The pinnules, which average 8 mm in length and 5 mm in width at the base, are slightly oblique and suboppositely attached to the rachis of the pinna. Pinnules at their bases are slightly rounded and expanded toward the anterior side of the margin; they are slightly confluent and gradually taper to an obtuse apex.

The nervation is distinct; the median vein is straight and thick. The lateral veinlets arise from the midvein at a wide angle and dichotomize near their base; the upper veinlets usually divide again.

REMARKS: *Eupecopteris fletti* has some similarity to *Pecopteris pseudobucklandii* Andrae and *P. polymorpha* Brongniart. The main difference from *P. pseudo-bucklandii* is that *E. fletti* has pinnules that are free and slightly rounded at the base, never decurrent, whereas the pinnules of the former species are neither expanded nor rounded on both sides at the base, and the lateral veinlets are divided into more branchlets. *E. fletti* is distinguished from *P. polymorpha* by its less divided lateral veinlets, by the rounded bases of its pinnules, which are never decurrent and always free, and by its densely apiculate rachises.

DISTRIBUTION: *Eupecopteris fletti* is a rare species; this is the first time it has been recorded from the Upper Carboniferous strata of the Llewellyn Formation (lower Westphalian D) in the Northern Anthracite coal basin of Pennsylvania. In England, this species is known from the Radstock Group of the Radstockian Series (Westphalian D).

SPECIMENS: WPMM F609, F684.

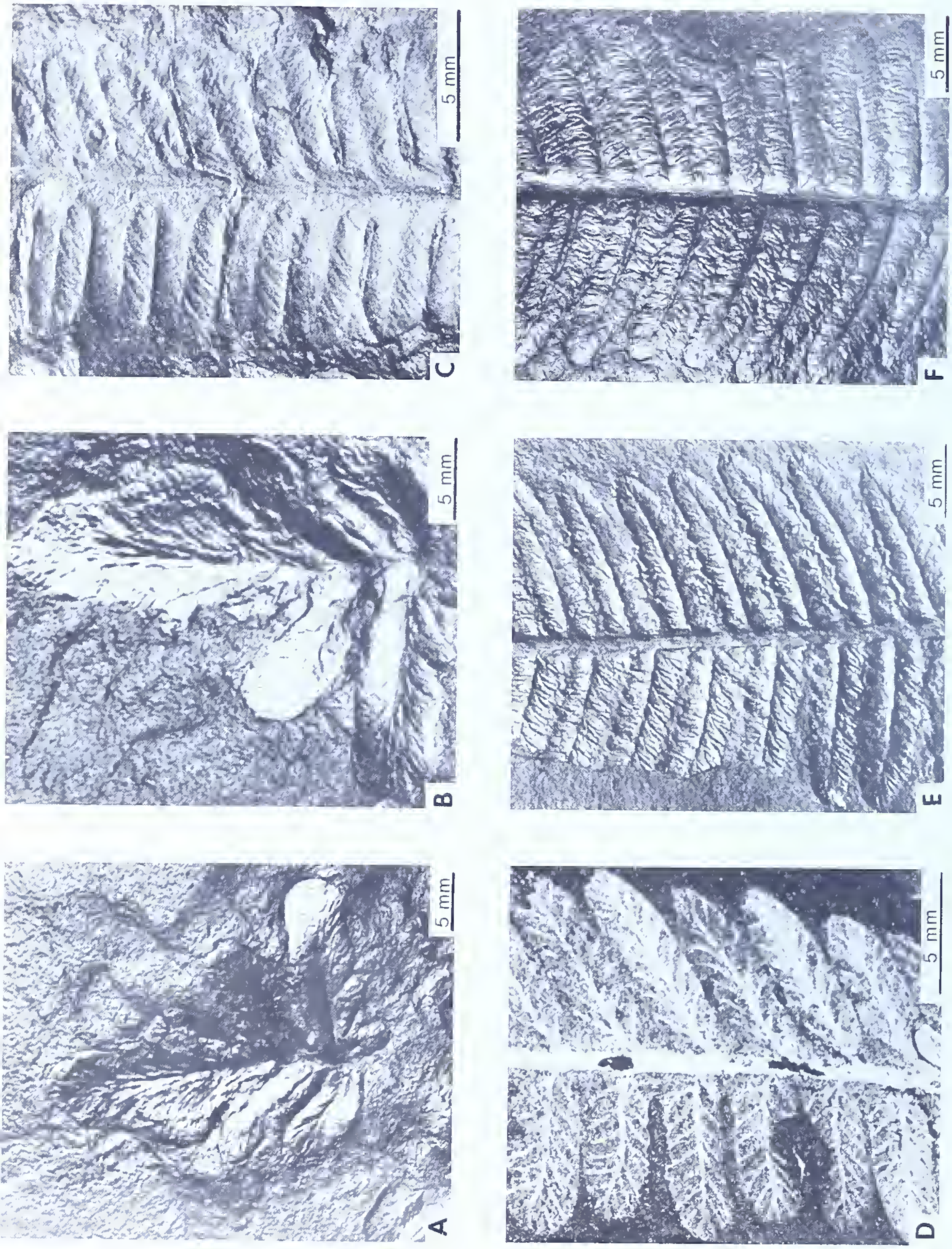
LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris hemitelioides Brongniart, 1828a
(Figure 16C, D)

Pecopteris hemitelioides Brongniart, 1828a, p. 314, pl. 108, figs. 1, 2.
Pecopteris (Asterotheca) hemitelioides Brongniart. Zeiller, 1886, pl. 11, figs. 6, 7; 1888, p. 133.
Asterotheca hemitelioides Brongniart. Kidston, 1924, p. 519, pl. 117, figs. 1, 2, 2a, 4, 5; text-fig. 60. (Contains a more complete synonymy.)
Pecopteris hemitelioides Brongniart. Gothan and Remy, 1957, p. 161, 190, 210, figs. 163, 204; chart 5.
Pecopteris hemitelioides Brongniart. Darrah, 1970, p. 132, pl. 19, fig. 2.
Pecopteris hemitelioides Brongniart. Oleksyshyn, 1976, p. 162, fig. 9D, E.

DESCRIPTION: The specimens represent fragments of sterile pinnae that have closely spaced pinnules alternately and nearly perpendicularly attached to a thick, straight rachis that bears on its surface linear cicatricules and apiculae. The pinnules, 7 to 8 mm long and 3 mm wide, sometimes are slightly contracted at the base, are free or touch each other laterally, and have parallel sides for about two thirds of their length, then slightly converge to a broadly rounded apex. The midvein is thick, straight, and nondecurrent, and extends nearly to the apex of the pinnule; the lateral veinlets arise from the midvein at a slight angle and are simple, straight, and sometimes slightly arcuate.

REMARKS: Similar fossil plants from the Sydney coal field, Nova Scotia, were previously described by Bell (1938, 1940) as *Asterotheca robbi.* Later, detailed descriptions of the venation and epidermal character of *P. hemitelioides* from the Saar coal basin by Corsin (1951) indicated that the species *A. robbi* must be considered as a synonym of *P. hemitelioides.* In the form of the pinnules, *P. hemitelioides* has some resemblance to *P. candolliana* Brongniart, but the rachis in the latter is smooth or has fine longitudinal striations, the thick midvein is decurrent at the base, and the lateral veinlets bifurcate slightly above their base into two arms. The pinnules are alternate and are upright or very slightly oblique to the rachis. The sides of the pinnules are parallel and the apices are bluntly rounded; some of the pinnules are slightly rounded at the base on the anterior side and decurrent on the posterior side. The pinnules are free, or occasionally touch each other laterally; they are two and one half to four times longer than broad (6 mm to 12 mm in length and 2 mm to 3 mm in breadth). The median vein is thick and straight, and is not decurrent at the base; it extends almost to the apex of the pinnule. The lateral veinlets arise from the midvein at a slight angle and are simple, straight, and sometimes feebly arcuate. In *P. cyathea* (Schlotheim) Brongniart: (1) the rachis is always smooth or has only fine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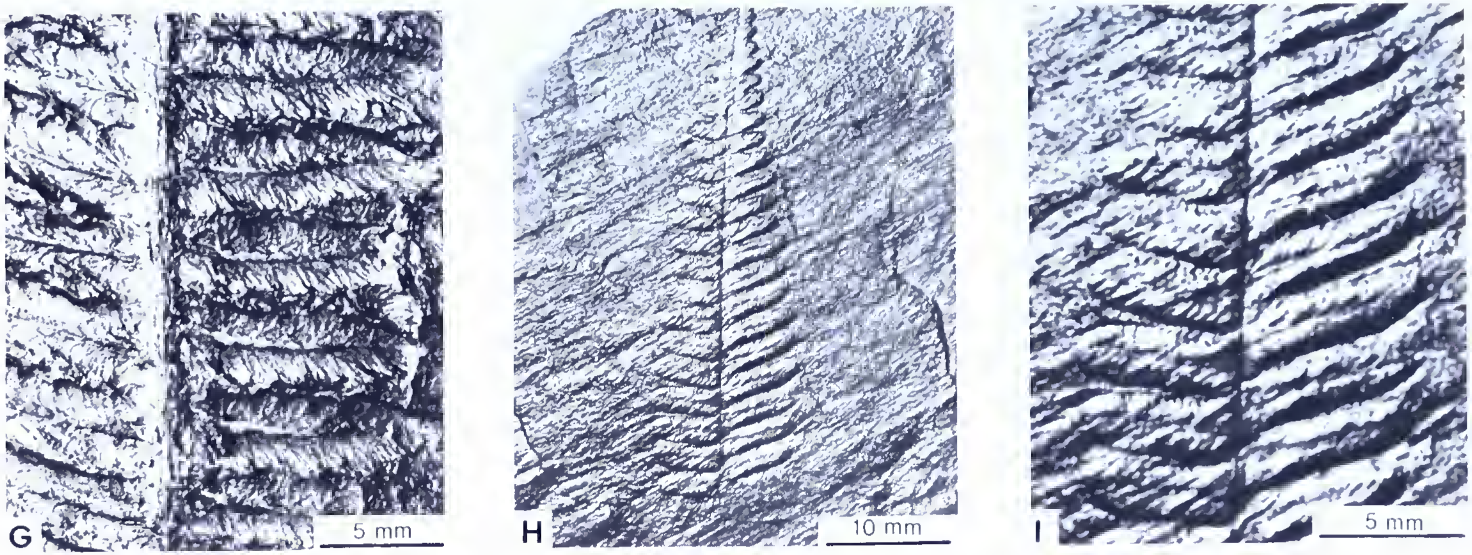


Figure 16. A, B. *Eupecopteris fletti* Kidston (tips of pinnae) [WPMM F609]; C, D. *Pecopteris hemitelioides* Brongniart [WPMM F685, F644]; E, F, G. *Pecopteris lamuriana* Heer [WPMM F626]; H, I. *Pecopteris lepidorachis* Brongniart [WPMM F619].

longitudinal striations; (2) the pinnules on the same pinna are often of different sizes; and (3) the lateral veinlets are simple or bifurcate once; the bifurcation of lateral veinlets may take place at the base of veinlets or at some distance above the base. *Pecopteris hemitelioides* is easily distinguished from *P. lepidorachis* Brongniart by its simple lateral veins; in the latter, the veins are always dichotomous and the rachis is punctate.

DISTRIBUTION: *Pecopteris hemitelioides* in the Appalachian region ranges from lower Alleghenian (Westphalian D) to lower Dunkardian (Lower Permian), but is most common in Conemaughian and Monongahelan strata (uppermost Westphalian D through Stephanian to Lower Permian). It is known from the Rhode Island Formation (Westphalian C to Lower Stephanian) in the Narragansett basin of New England in the United States, and from the Pictou Group of New Brunswick, Canada, and the Morien (Pictou) Group of the Sydney coal field (Westphalian D) in Nova Scotia, Canada. In Europe, this species ranges from the Westphalian D to Permian (Gothan and Remy, 1957).

SPECIMENS: WPMM F644, F685.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Pecopteris lamuriana Heer, 1865
(Figure 16E, F, G)

Pecopteris lamuriana Heer, 1865, p. 13, fig. 12.
Asterotheca lamuriana Heer. Kidston, 1925, p. 532, pl. 126, figs. 1, 1a, 1b, 2, 2a, 2b.
Pecopteris lamuriana Heer. Corsin, 1951, p. 312, pls. 186, 187, 188; text-fig. 80.
Pecopteris lamuriana Heer. Darrah, 1970, p. 138, pl. 15, figs. 3, 4; pl. 20, fig. 1; pl. 24, figs. 1, 2; pl. 42, figs. 1, 2; pl. 47, fig. 1.
Pecopteris lamuriana Heer. Lyons and Darrah, 1978, p. 436, fig. 31.

DESCRIPTION: The specimens represent fragments of secondary linear-lanceolate pinnae having thick, straight, longitudinally striated, apiculate rachises, to which the elongate tertiary pinnae ending in blunt points are attached alternately and nearly at right angles. The pinnules are small and alternate, having slightly convex margins and rounded apices attached to the rachis by whole bases. The pinnules on the lower portion of the pinnae are free, 2 to 3 mm long and 1.5 to 1.7 mm wide; the pinnules on the upper portion of the pinnae are smaller and united to each other, forming a crenulate margin on the pinnae.

Nervation consists of a strong median vein which extends almost to the apex of the pinnule; the lateral, arching veinlets bifurcate close to the base, but some of them bifurcate again before reaching, obliquely, the margin of the pinnule.

REMARKS: *Pecopteris lamuriana* in older collections has different names, such as *P. villosa* Brongniart, *P. abbreviata* (Brongniart) Lesquereux, *P. vestita* Lesquereux, *P. pseudovestita* D. White, and *P. miltoni* (Artis) Brongniart. *Pecopteris lamuriana* is usually associated with *Neuropteris ovata* Hoffmann forma *flexuosa* Sternberg and *Alethopteris serlii* (Brongniart) Goeppert, and probably was derived from *P. miltoni.*

DISTRIBUTION: *Pecopteris lamuriana* is moderately common in lower Alleghenian (Westphalian D_1) strata, but more frequently occurs in the upper Alleghenian and Conemaughian (Westphalian D and Stephanian A), and rarely occurs in the lower Monongahelan (lower Stephanian B) in the central and Appalachian regions and in the Narragansett basin in the United States. In Europe, this species is known from upper Westphalian D and Stephanian strata.

SPECIMEN: WPMM F626.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris lepidorachis Brongniart, 1828a
(Figure 16H, I)

Pecopteris lepidorachis Brongniart, 1828a, p. 313, pl. 103, figs. 1, 5.
Asterotheca lepidorachis Brongniart. Kidston, 1925, p. 525, pl. 127, figs. 1, 1a, 1b, 2, 2a; text-fig. 61. (Contains a more complete synonymy.)
Pecopteris lepidorachis Brongniart. Gothan and Remy, 1957, chart 5.
Pecopteris lepidorachis Brongniart. Darrah, 1970, p. 134, pl. 14, fig. 1; pl. 45, figs. 1, 2.

DESCRIPTION: The specimens represent separate lanceolate pinnae of the same width that gradually become contracted and pinnatifid, and finally assume the form of entire, elongated pinnules. The pinnules are alternate and oblong, and have parallel sides and bluntly rounded apices; they are mostly free, but some are slightly united near their bases. The pinnules are attached almost at right angles by the whole width of their base to a wide, straight, apiculate rachis.

Nervation is thin and indistinct; the median vein is straight, extending to the apex of the pinnule. The lateral veinlets are slightly arcuate, bifurcating into two veins near the base, and the superior branch sometimes divides again.

REMARKS: *Pecopteris lepidorachis* has often been confused with *P. candolliana* Brongniart. The pinnules of the latter are more or less distant and contracted at their bases, whereas those of *P. lepidorachis* are closely placed and not contracted at their bases. The rachis of *P. candolliana* is smooth or marked with delicate longitudinal striae, whereas in *P. lepidorachis* it is apiculate. The long, narrow form of the pinnules of *P. lepidorachis* also has some similarity to *P. hemitelioides* Brongniart, but in the latter species the lateral veinlets are undivided, whereas the lateral veinlets of *P. lepidorachis* branch once, and, in the longer pinnules, twice.

DISTRIBUTION: *Pecopteris lepidorachis* and *P. candolliana* rarely occur in middle Alleghenian (lower Westphalian D) strata; they are more common in upper Alleghenian, Conemaughian, Monongahelan, and lower Dunkardian (upper Westphalian D to Lower Permian) deposits in the central and Appalachian regions of the United States. In Europe, both species are known from Westphalian D, Stephanian, and Lower Rothliegend (Lower Permian) deposits.

SPECIMEN: WPMM F619.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris miltoni (Artis) Brongniart, 1828a
(Figure 17A, B)

Filicites miltoni Artis, 1825, pl. 14.

Pecopteris miltoni Artis. Brongniart, 1828a, p. 333, pl. 114, figs. 1-8; 1828b, p. 58, 170.

Pecopteris miltoni Brongniart. Lesquereux, 1879, pl. 41, fig. 9; 1880, p. 247.

Asterotheca miltoni (Artis). Kidston, 1924, p. 501, pl. 120, figs. 1-5; pl. 121; pl. 122, fig. 1; text-figs. 48, 54-57. (Contains a more complete synonymy.)

Asterotheca miltoni (Artis). Bell, 1938, p. 71, pl. 67, figs. 2-4; pl. 68; pl. 69, figs. 1-3.

Pecopteris miltoni Artis. Gothan and Remy, 1957, p. 114, 141, 189, 210, figs. 107, 201; chart 5.

DESCRIPTION: The specimens are represented by a large frond; tertiary pinnae are linear or linear-lanceolate, about 10 cm long and 1.4 cm broad, and of almost equal width except near the apex, where they suddenly contract and terminate bluntly. The pinnae are alternate and attached perpendicularly or slightly obliquely to a straight, broad, longitudinally striated rachis; some are free and some touch each other.

Pinnules are broad and alternate, varying in shape depending upon their position on the pinna and frond. The sides of the pinnules are straight and parallel, terminating abruptly in a broad apex. The pinnules are perpendicular or at a slightly oblique angle to the straight, longitudinally striated rachis. Pinnules on the lower pinnae are free or slightly connected at their bases; on the upper pinnae they become more joined to each other. Near the apex of the pinna, the margins of the pinnules become crenulate and terminate in an elongated fashion. The upper surface of the pinnules is often villous.

Nervation is often obscured by a villous covering. On pinnules near the tops of the pinnae, the median vein extends to near the apex, where it usually bifurcates. Lateral veinlets are oblique and dichotomize once near the base; the upper veinlet commonly divides again, depending upon the position and the shape of the pinnules. Smaller, more terminal, united pinnules have undivided veinlets.

REMARKS: *Pecopteris miltoni* has often been confused with *P. villosa* Brongniart, *P. vestita* Lesquereux, *P. pseudovestita* D. White, and *P. abbreviata* (Brongniart) Lesquereux. Later investigators included some of these species in *P. lamuriana* Heer, which probably evolved from *P. miltoni.*

DISTRIBUTION: In Europe, *Pecopteris miltoni* is a very widely distributed species in the Westphalian B and C; it is less common in the Westphalian D, and rare in the Stephanian. This species is not common in the United States; its fossil record there is based mainly on small fragments of fronds found in upper Pottsvillian and Alleghenian (Westphalian B, C, and lower D) strata of the central and Appalachian regions. It is also found in the Clifton and Minto Formations of the Pictou Group (lower Westphalian C) of New Brunswick, Canada.

SPECIMENS: WPMM F627, F682.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Pecopteris oreopteridis (Schlotheim) Sternberg, 1825
(Figure 17C, D)

Filicites oreopteridis Schlotheim, 1804, p. 36, pl. 6, fig. 9.

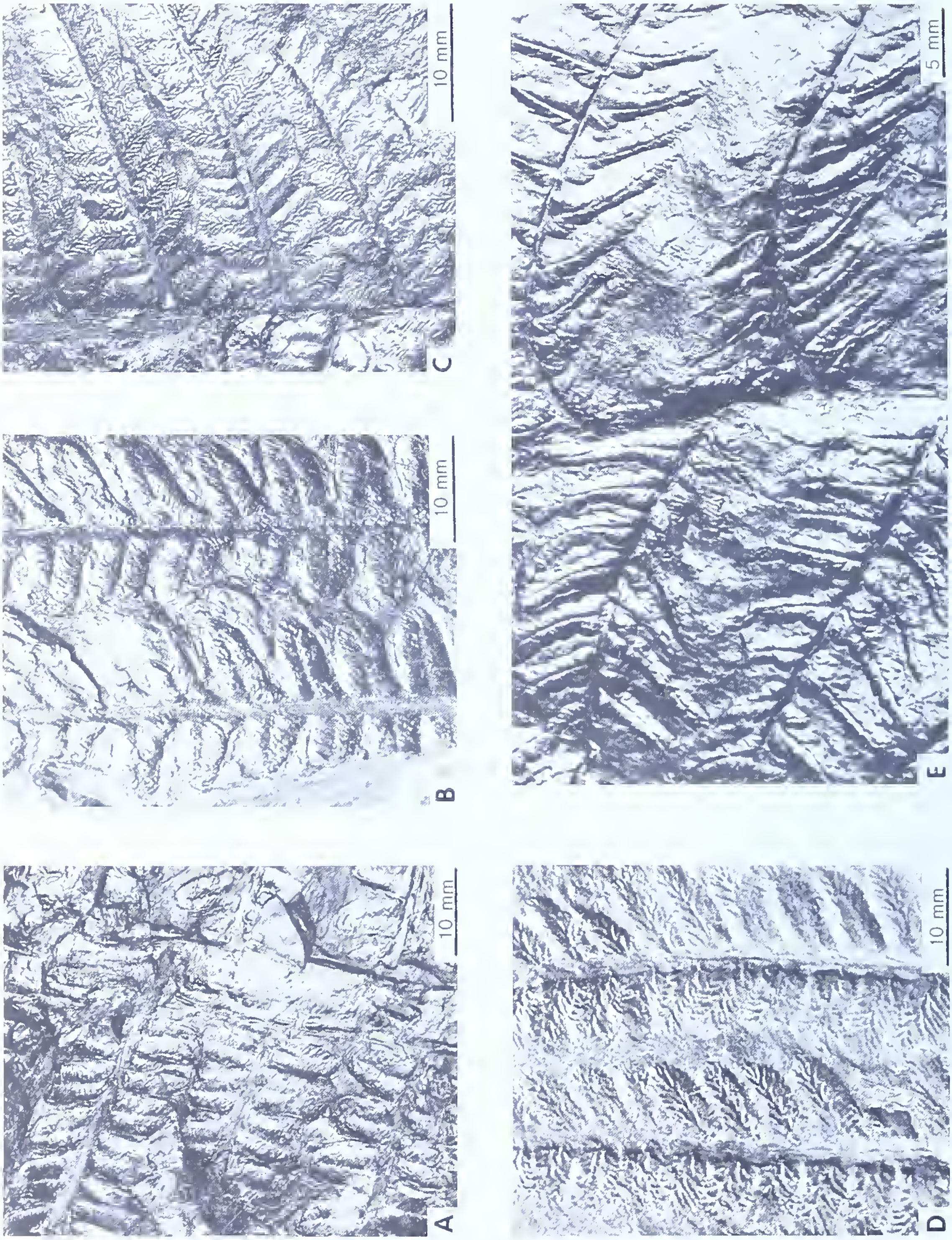
Pecopteris oreopteridis (Schlotheim). Sternberg, 1825, p. XIX; 1833, pl. 22, fig. 4.

Pecopteris oreopteridis Schlotheim. Lesquereux, 1879, pl. 41, fig. 8; 1880, p. 238.

Asterotheca oreopteridia Schlotheim. Kidston, 1924, p. 495, pl. 118, figs. 1, 1a, 2, 2a; pl. 119, figs. 1-4; text-figs. 51-53. (Contains a more complete synonymy.)

Pecopteris oreopteridis (Schlotheim). Darrah, 1970, p. 139-140.

DESCRIPTION: The illustrated specimen represents a large frond that is at least tripinnate; the main rachis is about 3 mm broad and has small punc-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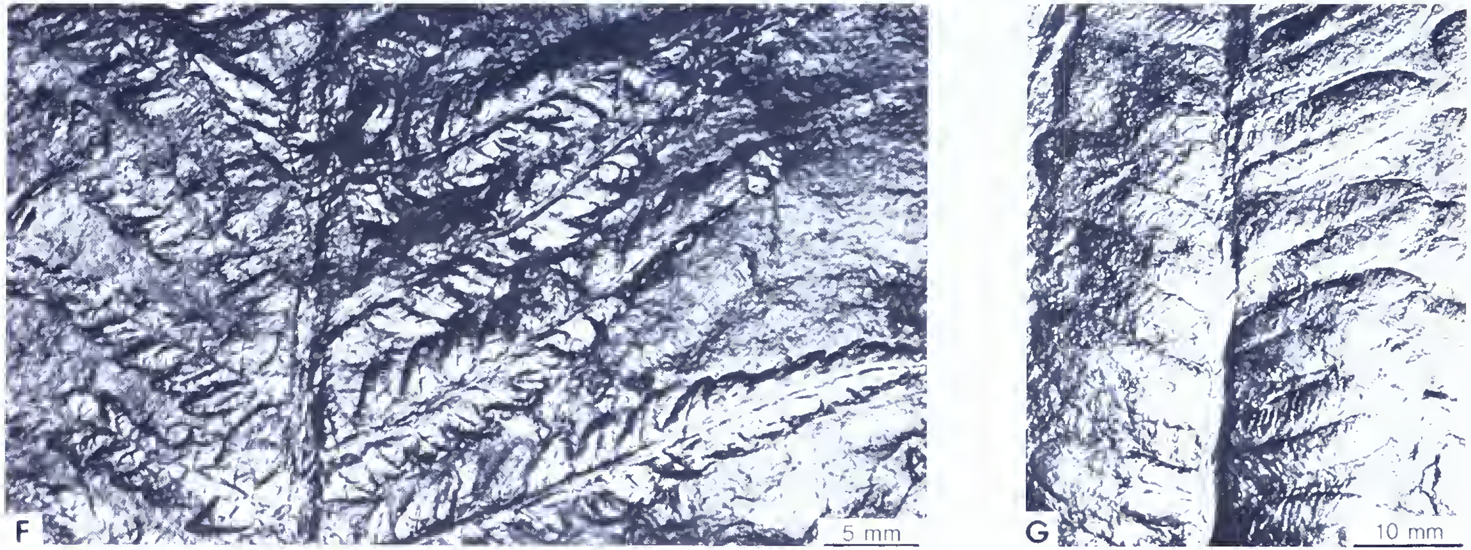


Figure 17. A, B. *Pecopteris miltoni* (Artis) Brongniart [WPMM F627, F682]; C, D. *Pecopteris oreopteridis* (Schlotheim) Sternberg [WPMM F683]; E, F. *Pecopteris plumosa* Artis forma *dentata* Brongniart [WPMM F530]; G. *Pecopteris* cf. *polymorpha* Brongniart [WPMM F698].

tae on its smooth surface, which indicate places where small hairs were attached. The secondary pinnae are alternate and linear-lanceolate, and ascend slightly outward from the rachis. They are free or touch each other laterally; some overlap each other in their upper portions. Some secondary pinnae attain a length of 10 cm and a width of about 1.5 cm near their bases.

The pinnules are alternate, oblong, and about one and one half to three times longer than broad; they have a blunt, rounded apex, and are slightly oblique to the rachis. The pinnules are contiguous, free, or slightly connected near their bases, and attached by the whole base, some slightly decurrent on the posterior side. The pinnules in the lower portion of the pinnae are larger than those near the top, where they gradually become more and more united to each other; at the extreme tip they assume the form of entire elongate pinnules with blunt apices.

Nervation is distinct; the median vein is straight or slightly decurrent, and extends nearly to the apex of the pinnule, where it divides into two veinlets. The lateral veins are moderately distinct, arising from the median vein at approximately 45 degrees, and dividing once near their bases; in the larger pinnules the upper branch sometimes bifurcates again.

REMARKS: *Pecopteris oreopteridis* might easily be confused with *P. miltoni* (Artis) Brongniart. The principal difference between these two species is that the latter is villous, i.e., usually covered with short, closely spaced hairs; those on the upper surface of the pinnules are of a fugaceous nature. When the hairs are not preserved, the different venation of these two species is usually indicative—in the free or slightly united pinnules of *P. miltoni* the anterior vein of the first dichotomy of the lateral veinlets almost always divides again (Kidston, 1924, p. 499).

DISTRIBUTION: *Pecopteris oreopteridis* is known from middle Alleghenian to Monongahelan (Westphalian D and Stephanian A, B, and C) strata in the central and Appalachian regions and in the Narragansett basin of the United States. In Europe, this species is known from Westphalian D to Rothliegend (Lower Permian) (Gothan and Remy, 1957, chart 5).

SPECIMEN: WPMM F683.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris plumosa Artis forma *dentata* Brongniart, 1828
(Figure 17E, F)

Filicites plumosus Artis, 1825, p. 17, pl. 17.

Pecopteris plumosa (Artis). Brongniart, 1828a, p. 348, pl. 121, figs. 1-2; pl. 122, figs. 1-4; 1828b, p. 58, 171.

Pecopteris dentata Brongniart, 1828b, p. 346, pls. 123, 124.
Pecopteris dentata Brongniart. Lesquereux, 1879, pl. 44, figs. 4, 4a; 1880, p. 240.
Pecopteris (Dactylotheca) dentata Brongniart. White, 1899, p. 75, pl. 24, figs. 1, 2; pl. 25; pl. 26, figs. 2-4; pl. 27.
Dactylotheca plumosa forma *dentata* (Brongniart). Bell, 1938, p. 76, pl. 73; pl. 77, figs. 3, 4; pl. 80, figs. 1, 3.

DESCRIPTION: The specimen represents a large frond, tripinnate in the upper portion and quadripinnate towards its base; the main rachis is straight, 1 to 4 mm broad, and densely punctate, having very small papilla-like emergences. The primary pinnae are alternate, about 10 mm apart, slightly oblique to the rachis, and often reflexed in the lower portion of the frond, usually slightly overlapping each other; they are ovate-lanceolate, about 10 cm long and 3.5 cm wide at the middle, and usually contracted at the base, having nearly parallel sides in the middle portion, tapering to a sharp point above. The secondary pinnae are alternate or subopposite, and 4 to 5 mm apart; some overlap each other. They are more or less oblique to the rachis, and the lower one is often reflexed and shorter. They are often flexuous and are linear-lanceolate, some attaining a length of 40 mm and a width of 7 mm, tapering to an obtusely acuminate point. The uppermost ultimate pinnae and the terminal portions of secondary pinnae are usually more or less united, lobed, and crenulate, and gradually become entire at the tip.

The pinnules are alternate; the basal pinnules are larger, more or less deltoidal or triangular, somewhat arched, obtusely pointed or rounded, and often acuminate at the tip and slightly connate at the base; many grade into dentate or conulate forms. The pinnules are more or less oblique to a longitudinally grooved rachis.

Nervation is distinct; the median vein is straight or slightly decurrent in the larger pinnules and extends to the top of the pinnule. The lateral veinlets are divided; in dentate pinnules a single lateral veinlet enters each dentation.

REMARKS: *Pecopteris plumosa* forma *dentata* is an extremely polymorphic fern that has various forms of pinnules in different portions of the frond. The shape of the pinnules changed through time; the delicate, plumose type of pinnules is characteristic of earlier forms, whereas the more robust type having broader, more obtuse pinnules and stronger venation is characteristic of later forms (White, 1899, p. 78).

DISTRIBUTION: *Pecopteris plumosa* forma *dentata* ranges from the middle Pottsvillian to the Monongahelan. It is abundant in the upper Pottsvillian and Alleghenian and their equivalents (Westphalian B, C, and lower D) and rare in the Conemaughian and Monongahelan (uppermost Westphalian D and Stephanian). It is known from the central and Appalachian regions of the United States, and from the Cumberland Group (Westphalian B) in the Cumberland coal field of Nova Scotia, Canada. In Europe, this polymorphic fern ranges from the Namurian B throughout the Westphalian and Stephanian to the Lower Rothliegend. It is extremely rare in the Namurian B and C, fairly common in the Westphalian and Stephanian A, and rare in the Stephanian B and C and Lower Permian.

SPECIMEN: WPMM F530.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris cf. *polymorpha* Brongniart, 1828a
(Figure 17G)

Pecopteris polymorpha Brongniart, 1828a, p. 331, pl. 113, figs. 1-6; 1828b, p. 56.
Pecopteris polymorpha Brongniart. Zeiller, 1880, p. 91, pl. 119, figs. 1-3.
Pecopteris polymorpha Brongniart. Sellards, 1908, p. 68, pl. 20, fig. 2.
Acitheca polymorpha Brongniart. Kidston, 1925, p. 539, pl. 128, figs. 1, 1a; pl. 129, figs. 1, 1a, 1b, 2, 2a, 3, 4; pl. 130, figs. 3, 3a, 4, 4a; text-figs. 67-69. (Contains a more complete synonymy.)
Pecopteris polymorpha Brongniart. Darrah, 1970, p. 141, pl. 19, fig. 1.

DESCRIPTION: The illustrated specimen shows ultimate, linear-lanceolate pinnae, which touch each other laterally, taper gradually upward from the base, and terminate in obtusely pointed lobes. The rachis is undulate and has fine longitudinal striae and minute punctae. The pinnules are alternate, perpendicular or slightly convex, and bluntly rounded at the apex; they are about three times longer than broad.

Nervation is distinct; the median vein is thick and straight, extending to near the apex, where it divides twice. The lateral veinlets dichotomize immediately above the base, and each branch again divides, reaching the margin of the pinnule at an open angle.

REMARKS: The ultimate pinnae of *P. polymorpha* may be easily confused with the pinnae of *P. miltoni* (Artis) Brongniart, especially when the venation of the pinnules is not well preserved. The main differences between these two species are that the upper surface of the pinnules in *P. polymorpha* is smooth, whereas in *P. miltoni* it is villous; the midvein of the pinnules situated in the central region of the frond in *P. polymorpha* is always straight and thick, whereas in *P. miltoni* it is decurrent. The pinnules of the central region of the frond in *P. polymorpha* have four or five lateral veins that reach the margin at a wide angle, whereas in *P. miltoni* the bundle divides three times and the veins take a more oblique course to the margin of the pinnule.

DISTRIBUTION: *Pecopteris polymorpha* is known from the upper Alleghenian through the middle Dunkardian (Westphalian D to Lower Permian) in the central and Appalachian regions, and from the Narragansett basin (Westphalian D to lower Stephanian) in New England. In Europe, this species is known from the uppermost Westphalian to the Rothliegend (Lower Permian).

SPECIMEN: WPMM F698.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Pecopteris unita Brongniart, 1828a
(Figure 18A, B, C, D, E)

Pecopteris unita Brongniart, 1828a, p. 342, pl. 116, figs. 1-5; 1828b, p. 58, 170.

Pecopteris unita Brongniart. Lesquereux, 1879, pl. 40, figs. 1-7; 1880, p. 223.

Ptychocarpus unitus Brongniart. Kidston, 1925, p. 548, pl. 131, figs. 1-9, 9a; text-figs. 70, 71. (Contains a more complete synonymy.)

Ptychocarpus unitus (Brongniart). Bell, 1938, p. 77, pl. 72, fig. 2; pl. 73, figs. 4-6.

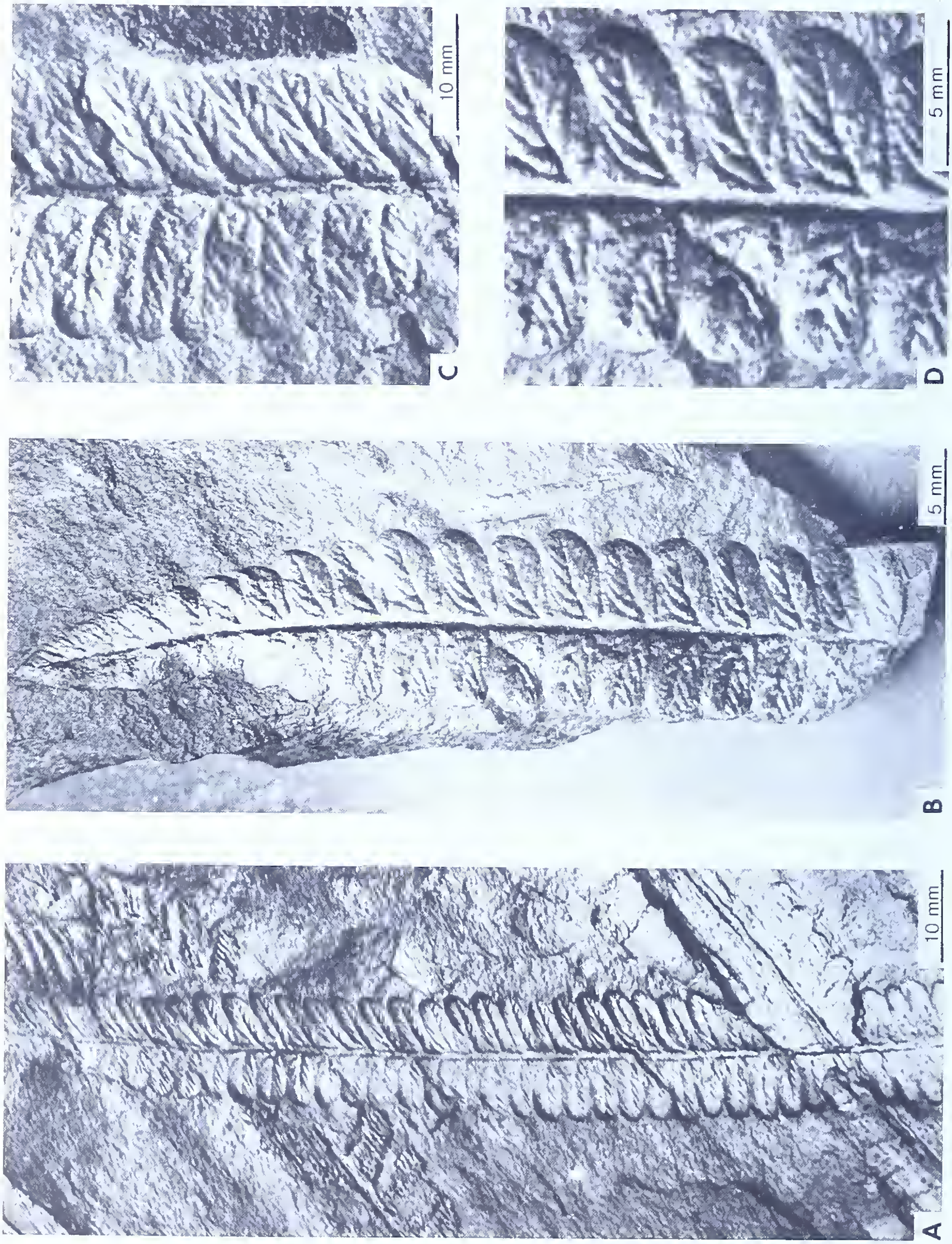
Pecopteris unita Brongniart. Gothan and Remy, 1957, p. 163, 164, 190, 212, figs. 166, 208; chart 5.

Pecopteris unita Brongniart. Darrah, 1970, p. 143, pl. 14, figs. 2, 3; pl. 15, figs. 1, 2.

DESCRIPTION: The pinnae of the figured specimens are linear-lanceolate and slightly contracted at the base, tapering at the apex and terminating in an obtuse point. The pinnules are alternate, have parallel margins and rounded apices, and attain a length of 7 mm and a width in the middle of 3 mm; they are contiguous, slightly decurrent, and more or less united to each other in the lower part to completely entire at some apices. The rachis of the pinna is broad and longitudinally striated. The midrib of the pinnules is decurrent, extending nearly to the apex, where it frequently divides into two veinlets; the lateral veins are subopposite, simple, and arcuate, extending nearly to the margin. Fructification is not evident.

REMARKS: *Pecopteris unita* is easily distinguished by the fact that its pinnules are more or less united to each other, and by the fact that its lateral veinlets are subopposite, undivided, and more or less distinctly arcuate.

DISTRIBUTION: *Pecopteris unita* is known from Alleghenian, Conemaughian, Monongahelan, and Dunkardian strata and their equivalents (Westphalian D to Lower Permian) in the central and Appalachian regions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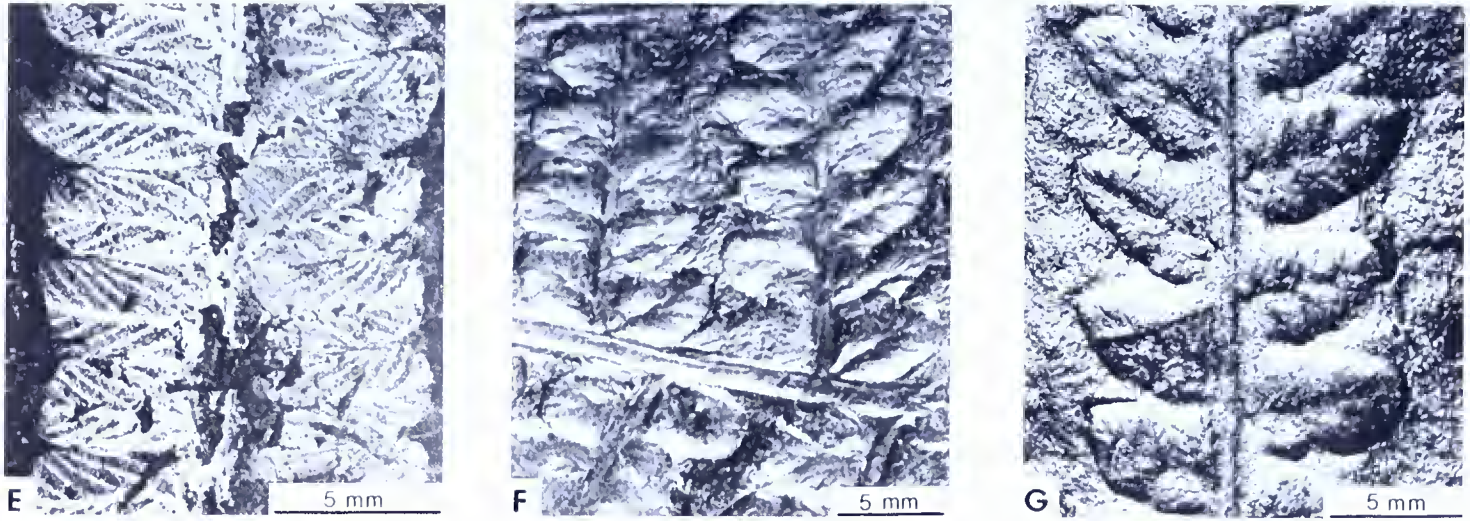


Figure 18. A. *Pecopteris unita* Brongniart [WPMM F536]; B, C, D. *Pecopteris unita* Brongniart [WPMM F683]; E. *Pecopteris unita* Brongniart (nervation of pinnules) [WPMM F643]; F, G. *Dicksoniites pluckenetii* (Schlotheim) Sterzel [WPMM F651].

of the United States, and from the *Ptychocarpus unitus* Zone, upper Morien Series (Westphalian D) of the Sydney coal field in Nova Scotia, Canada. In Europe, this species is known from the Westphalian D, Stephanian A, B, and C, and Lower Rothliegend (Lower Permian).

SPECIMENS: WPMM F536, F643, F683.

LOCALITIES: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed; and Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Family DICKSONIACEAE Hirmer

Genus *Dicksoniites* Sterzel, 1881

Dicksoniites pluckenetii (Schlotheim) Sterzel, 1881

(Figure 18F, G)

Filicites pluckenetii Schlotheim, 1804, p. 52, pl. 10, fig. 19; 1820, p. 410.
Pecopteris pluckenetii Sternberg, 1825, p. 19, 150.
Pecopteris pluckeneti Schlotheim. Lesquereux, 1879, pl. 34, figs. 44, 44a; pl. 35, figs. 7, 7a; 1880, p. 199.
Dicksoni(i)tes pluckeneti (Schlotheim). Sterzel, 1881, p. 223, 225; 1883, p. 1, pl. 6, figs. 1-6.
Dicksonites pluckeneti Schlotheim. Kidston, 1924, p. 400, pl. 109, figs. 1-4; text-figs. 33-36. (Contains a more complete synonymy.)
Dicksonites pluckeneti (Schlotheim). Bell, 1938, p. 77, pl. 77, fig. 2; pl. 78, fig. 2; pl. 79, figs. 1, 2.

DESCRIPTION: The specimens preserve fragmentary portions of this plant. The upper portion of a typical frond has a strong, finely punctate and irregularly striated rachis to which the ultimate pinnae are attached nearly at right angles. The pinnae are 8 to 9 mm long, alternate or subopposite, free or touching laterally, linear-lanceolate, and broadest in the middle; they taper to a narrow, obtuse lobe.

The pinnules are slightly oblique to the rachis, and are commonly contracted at the base and attached by a stalk; the terminal lobe, if present, is obtuse. The lower, larger pinnules are ovate to subtriangular and have two or three lobes separated by a deep sinus; more distally, the pinnules become connate, and in the apical region they are more or less united and commonly slightly decurrent. The rachis is undulate.

The median vein of the free pinnules is prominent, slightly decurrent at the base, flexuous, and divided at the summit. The lateral veinlets dichotomize two or three times.

REMARKS: The entire, ovate to subtriangular pinnules of *Dicksoniites pluckenetii* have been confused with those of *Mariopteris nervosa* (Brongniart) Zeiller, but accurate observation shows differences in the venation and the form of the basal pinnules in these two species: (1) *D. pluckenetii* has pinnate venation and its basal pinnules have an oval to subtriangular shape; (2) the rachises of *D. pluckenetii* divide into two arms at an open angle and are marked by numerous delicate longitudinal striations and numerous transverse elevations; (3) *M. nervosa* has straight or slightly flexuous rachises, which very often have one or two ridges on their surfaces. Terminal-pinnae fragments of *Pecopteris plumosa* Artis forma *dentata* Brongniart have also been confused with *D. pluckenetii.*

DISTRIBUTION: *Dicksoniites pluckenetii* is rare in the Alleghenian (lower Westphalian D), but is more common in Conemaughian, Monongahelan, and lower Dunkardian (uppermost Westphalian D, Stephanian, and Lower Permian) strata in the United States. It also occurs in the *Ptychocarpus unitus* Zone, ranging from the Emery seam to the top of the Morien (Pictou) Group (Westphalian D) of the Sydney coal field in Nova Scotia, Canada. In Europe, this species is known from the Westphalian D, Stephanian A, B, and C, and Lower Rothliegend (Lower Permian).

SPECIMEN: WPMM F651.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Class PTERIDOSPERMOPSIDA
Order PTERIDOSPERMALES
Family ALETHOPTERIDACEAE
Genus *Alethopteris* Sternberg, 1825
Alethopteris ambigua Lesquereux, 1880
(Figure 19A)

Alethopteris ambigua Lesquereux, 1879, pl. 31, figs. 1-4; 1880, p. 182.
Alethopteris ambigua Lesquereux. White, 1899, p. 113, pl. 37, figs. 3, 4; pl. 41, fig. 9.
Alethopteris ambigua Lesquereux. Cridland, 1968, p. 107, figs. 1-13.
Alethopteris ambigua Lesquereux (emended). Darrah, 1970, p. 117.

DESCRIPTION: The figured specimen represents a lanceolate pinna having a strong, longitudinally striated rachis. The pinnules are subopposite, lingulate, slightly contracted and united at the base, and obtusely rounded at the apex; the side margins are nearly parallel. The midvein is thick and deeply depressed on the upper side; in the upper part near the apex of the pinnule it splits into a few thin, bifurcating veinlets. The lateral veinlets are distant, partially obscure on the upper surface, and slightly oblique; they are simple or fork once into two arms near the base, and the upper arm usually forks again.

REMARKS: The close similarity of *Alethopteris ambigua* to *A. gibbsonii* Lesquereux and *A. friedelii* P. Bertrand makes identification of these species very difficult; therefore, a critical reexamination of these species is badly needed.

DISTRIBUTION: In the United States, *Alethopteris ambigua* ranges from upper Pottsvillian to lowest Monongahelan (Westphalian C to Stephanian B); it is most frequent in the uppermost Pottsvillian and lowest Alleghenian and rare in the Conemaughian and Monongahelan.

SPECIMEN: WPMM F538.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Alethopteris decurrens (Artis) Zeiller, 1888
(Figure 19B, C)

Filicites decurrens Artis, 1825, pl. 21.
Alethopteris decurrens Artis. Zeiller, 1886, pl. 34, figs. 2, 3; pl. 35, fig. 4; pl. 36, figs. 3, 4; 1888, p. 221.
Alethopteris decurrens (Artis). Bell, 1944, p. 87, pl. 40, fig. 5; pl. 41, figs. 2, 3; pl. 42, fig. 5; pl. 60, figs. 5, 6.
Alethopteris decurrens Artis. Crookall, 1955, p. 26, pl. 2, figs. 1-3; pl. 6, fig. 3; text-fig. 8. (Contains a more complete synonymy.)

DESCRIPTION: The specimens represent a few separate pinnae that have nearly straight pinnules. The longer pinnules are almost linear, and the shorter pinnules have the form of an elongated triangle; they are widest in their lowest third. The pinnules are obliquely attached to the rachis, and do not touch each other along their slightly arched margins. The upper margin of the pinnules is slightly contracted at the base; the lower margin is usually decurrent on the rachis and often connects with the adjacent pinnule. The sinus between adjacent pinnules is sharp.

The midvein is broad and very strongly marked, slightly decurrent at the base and extending nearly to the apex of the pinnule. Lateral veinlets extend from the midvein at right angles, arch very slightly once at the base, and meet the margin of the pinnule almost at right angles; some subsidiary veins enter the decurrent pinnules from the rachis, which bears fine longitudinal striae.

REMARKS: *Alethopteris decurrens* is very easily confused with some forms of *A. lonchitica* (Schlotheim) Brongniart. The main difference between these two species is that the pinnules of *A. decurrens* are typically linear and not more than 3 mm broad, whereas the pinnules of *A. lonchitica* are broader (3 to 5 mm), often swollen about the middle, and lanceolate or ovate-lanceolate in shape. In *A. decurrens*, as in *A. lonchitica*, the basal pinnules of some secondary pinnae may not be decurrent on the rachis but neuropteroid at the base. The venation of *A. decurrens* is distinctly more distant than the venation of *A. lonchitica*.

DISTRIBUTION: *Alethopteris decurrens* is known from Pottsvillian and Alleghenian (Westphalian A to D) strata in the central and Appalachian regions of the United States, and from Riversdale and Cumberland (Westphalian A to lower B) strata in Nova Scotia, Canada. In Europe, this species ranges from the Westphalian A to D, but is most common in the Westphalian D.

SPECIMENS: WPMM F625, F642.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Alethopteris friedelii P. Bertrand, 1932
(Figure 19D, E)

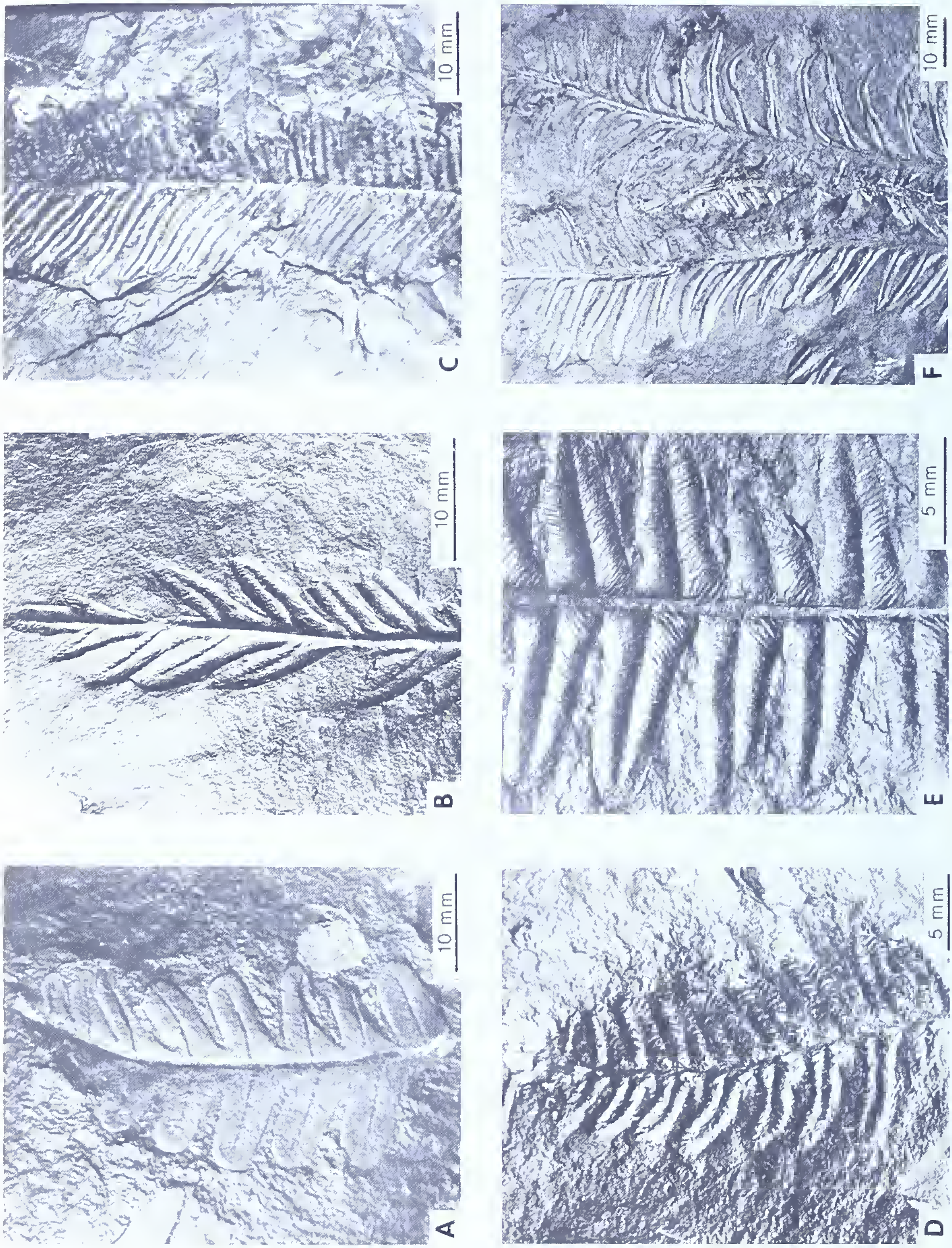
Alethopteris friedeli P. Bertrand, 1932, p. 70, pl. 6, figs. 36-42; text-fig. 10.
Alethopteris friedeli P. Bertrand. Bell, 1938, p. 68, pl. 62, figs. 2-4; pl. 63.
Alethopteris davreuxi Brongniart var. *friedeli* P. Bertrand. Crookall, 1955, p. 11, pl. 3, figs. 1, 1a, 1b; pl. 10, fig. 2; text-figs. 3, 4, 14C, G. (Contains a more complete synonymy.)
Alethopteris friedeli P. Bertrand. Darrah, 1970, p. 118.

DESCRIPTION: The specimens represent a few fragments of secondary pinnae that have many pinnules alternately attached to slightly flexuous rachises, which are ornamented by numerous fine longitudinal striations and, in some cases, fine punctae.

The pinnules vary in size, shape, and attachment; they have straight margins and rounded or bluntly pointed apices. Adjacent pinnules usually do not touch each other but are commonly separated by a sinus; pinnules in the lower portion of a pinna, about 3 mm in breadth, are pecopteroid (perpendicular to the rachis), whereas in the upper portion they are shorter, obliquely attached, slightly decurrent on the rachis, and more or less joined together at the base.

Venation is prominent; the median vein is well marked, broad, sometimes very slightly decurrent at the base, and straight, ending rather abruptly before reaching the apex. Lateral veinlets are distinct and slightly oblique to the midvein; they divide once or twice and meet the margin of the pinnule at almost right angles.

REMARKS: *Alethopteris friedelii* has some similarity to *A. grandinii* Brongniart, *A. serlii* Brongniart, and *A. lonchitica* (Schlotheim) Brongni-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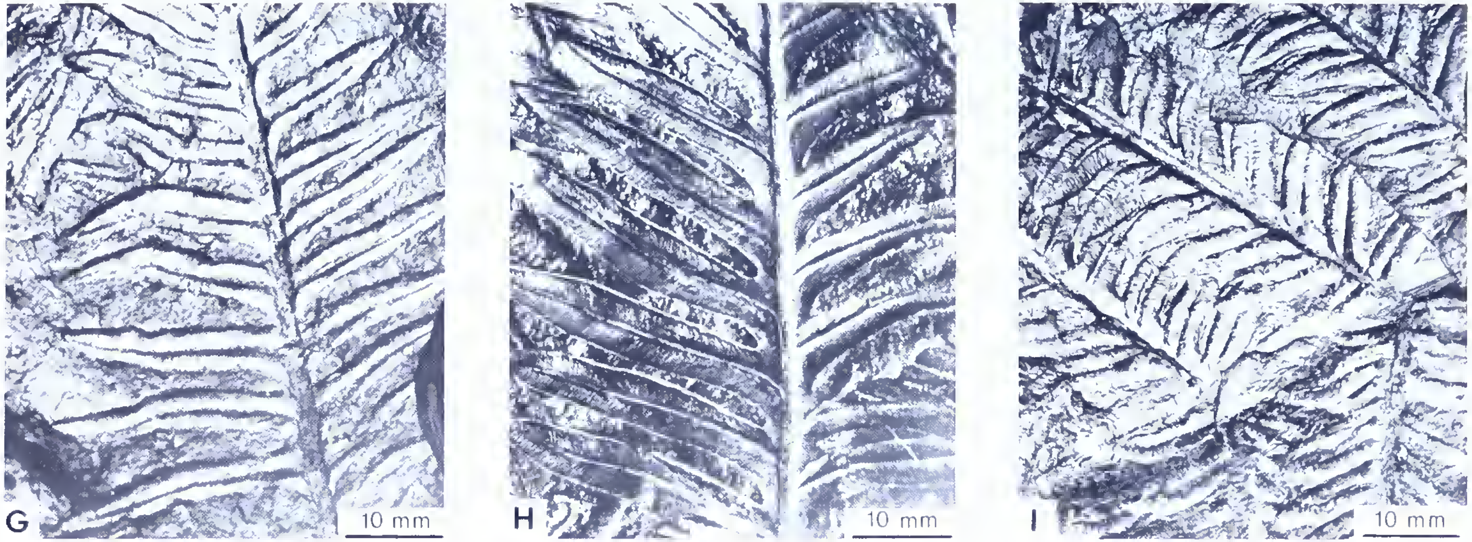


Figure 19. A. *Alethopteris ambigua* Lesquereux [WPMM F538]; B, C. *Alethopteris decurrens* (Artis) Zeiller [WPMM F625, F642]; D, E. *Alethopteris friedelii* P. Bertrand [WPMM F699]; F, G, H. *Alethopteris lonchitica* (Schlotheim) Brongniart [WPMM F618, F541]; I. *Alethopteris serlii* (Brongniart) Goeppert [WPMM F700].

art. The main difference between *A. friedelii* and *A. grandinii* is that the former has more elongated pinnules that are not basally united as in the latter species. The lateral veinlets of the pinnules of *A. friedelii* are thicker and more distant than those of *A. serlii* and *A. lonchitica. Alethopteris gibbsonii* Lesquereux and *A. ambigua* Lesquereux are closely related to *A. friedelii*, if not identical.

DISTRIBUTION: *Alethopteris friedelii* is known from upper Pottsvillian and Alleghenian (Westphalian B, C, and lower D) strata in the central and Appalachian regions of the United States, from the Morien (Pictou) Group in the Sydney coal field of Nova Scotia, Canada, and from the Pictou Group (Westphalian C and D) in New Brunswick, Canada. In Europe, this species is known from the Westphalian A, B, C, and D.

SPECIMEN: WPMM F699.

LOCALITIES: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed; and Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Alethopteris lonchitica (Schlotheim) Brongniart, 1828a
(Figure 19F, G, H)

Filicites lonchiticus Schlotheim, 1820, p. 411.
Pecopteris lonchitica (Schlotheim). Brongniart, 1828a, p. 275, pl. 84, figs. 1-7; 1828b, p. 57, 170.
Alethopteris lonchitica Schlotheim. Lesquereux, 1879, pl. 28, fig. 7; 1880, p. 177.
Alethopteris lonchitica (Schlotheim). Bell, 1938, p. 67, pl. 61, fig. 5.
Alethopteris lonchitica Schlotheim. Crookall, 1955, p. 22, pl. 5, figs. 1, 2; pl. 10, figs. 1, 3; text-figs. 7, 148. (Contains a more complete synonymy.)

DESCRIPTION: The secondary pinnae in the figured specimens are linear-lanceolate, and each has a thick, longitudinally striated rachis. The pinnules are slender and linear-lanceolate or oval-lanceolate; they are obliquely and alternately attached to a thick, longitudinally striated rachis, and range from 8 to 50 mm in length and 3 to 6 mm in width, tapering gradually either to a bluntly pointed or to a slightly acuminate apex. Small pinnules near the top of the pinna are often contiguous, but the larger pinnules below do not touch each other along their margins. The upper margin of the pinnules is usually slightly contracted at the base, whereas the lower margin is strongly decurrent and united with the adjacent pinnule, forming a sharp sinus. The terminal pinnule of the secondary pinnae is linear to linear-lanceolate, and in some specimens is about 35 mm long; it tapers to a bluntly pointed apex.

The broad and deep, slightly decurrent midrib extends to the apex of the pinnule. Numerous closely spaced, fine lateral veinlets arise from the midvein at almost right angles; they are slightly arched and meet the margin of the pinnule at right angles or nearly so. Some lateral veinlets are simple and undivided, but most of them dichotomize once or twice.

REMARKS: There are considerable variations in the size and shape of pinnules according to their position on the pinna. Relatively small pinnules, broader in proportion to their length and having strongly arched margins, resemble *Alethopteris serlii* (Brongniart) Goeppert, whereas long-pinnuled forms of *A. serlii* have considerable resemblance to *A. lonchitica*. This latter species has typically more distant pinnules, which are less united at the base and narrower than those of *A. serlii*. Also, the lateral veinlets of *A. lonchitica* are more distinct and more distant than those of *A. serlii*, and the apex of the pinnule of *A. lonchitica* tapers much more gradually than in *A. serlii*.

The presence of *A. lonchitica* in the Westphalian A and B (also in the Namurian C in Europe) and rarely in the Westphalian C and D, and of *A. serlii* in the Westphalian C and more commonly in the Westphalian D, indicates that the latter species may have evolved from *A. lonchitica*. This probability was taken into consideration by Gothan (1953, pl. 4, fig. 3), and Gothan and Remy (1957, fig. 112; chart 5), who combined *A. serlii* with *A. lonchitica*, but distinguished the former as a special form of the latter, marking the geologic time range of *A. lonchitica* forma *serlii* from Late Namurian to Westphalian D.

DISTRIBUTION: *Alethopteris lonchitica* occurs more commonly in Pottsvillian and lower Alleghenian (Westphalian A, B, C, and D_1) strata, and rarely in upper Alleghenian and lower Conemaughian (Westphalian D_2) strata in the central and Appalachian regions of the United States. It also occurs in the Minto Formation (Pictou Group) of New Brunswick, Canada, and in the Cumberland and Morien (Pictou) Groups of Nova Scotia, Canada. In Europe, this species is known from Namurian C and Westphalian A and B strata, and rarely from Westphalian C strata.

SPECIMENS: WPMM F541, F618.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Alethopteris serlii (Brongniart) Goeppert, 1836
(Figures 19I; 20A, B, C, D)

Pecopteris serlii Brongniart, 1828a, p. 292, pl. 85; 1828b, p. 57, 170.
Alethopteris serlii (Brongniart). Goeppert, 1836, p. 301, pl. 21, figs. 6, 7.

Alethopteris serlii Brongniart. Lesquereux, 1879, pl. 29, figs. 1-5; 1880, p. 176.

Alethopteris serli (Brongniart). Bell, 1938, p. 67, pl. 61, figs. 6, 7; pl. 62, fig. 1.

Alethopteris serli Brongniart. Crookall, 1955, p. 17, pl. 7, figs. 1, 2, 2a, 3; text-figs. 6, 14B, 17C. (Contains a more complete synonymy.)

Alethopteris serlii (Brongniart) Goeppert. Oleksyshyn, 1976, p. 163, fig. 10A.

DESCRIPTION: The species is represented by a large frond. The secondary pinnae are elongate-lanceolate, and oppositely attached to a strong, longitudinally striated rachis, about 5 mm thick; the pinnae differ in length. The pinnules are oblong, alternate or subopposite, and usually obliquely attached to a narrowly alate rachis; adjacent pinnules are separated from each other by a sharp sinus. The upper margin of the pinnules is slightly decurrent and unites adjacent pinnules; the pinnules are widest in the middle and taper rapidly to a blunt or slightly acuminate apex. Terminal pinnules usually are slightly undulate and are lanceolate, having bluntly pointed apices. The sizes of the pinnules vary, but the most common are 15 to 20 mm long by 6 to 8 mm broad at the widest part.

The midvein is strong, broad, and slightly decurrent at the base; it usually extends to the apex of the pinnule or divides into veinlets near the apex. Numerous closely spaced lateral veinlets arise at a slightly oblique angle from the midvein, arch slightly, and usually divide once or twice. Some veinlets are simple; subsidiary veinlets enter the pinnules directly from the rachis.

REMARKS: *Alethopteris serlii* is one of the most widespread of the seed-ferns (Pteridosperms). Polymorphism in the size, shape, and position of pinnules on the pinnae has often caused misidentification. Very often this seed-fern was described under different specific names, such as *A. lonchitica* (Schlotheim) Brongniart and *A. grandinii* (Brongniart) Goeppert. The pinnules of *A. serlii* are broader in proportion to their length than those of *A. lonchitica*, wider in the middle, and united at the base; the lateral veinlets are more numerous, more closely spaced, and more often dichotomized near the middle of the pinnule than those of *A. lonchitica*. Some short-pinnuled forms of *A. lonchitica* are confused with *A. serlii*, and the long-pinnuled forms of *A. serlii* are confused with *A. lonchitica*. The latter usually has slender pinnules that have less convex sides than those in the typical *A. serlii*.

In *A. serlii* both the apices of the pinnules and the sinuses separating adjacent pinnules are more or less sharp, whereas in *A. grandinii* they are more distant from each other and divide from one to three times. The lateral veinlets of *A. serlii* arise from the midvein nearly perpendicularly or obliquely, whereas in *A. grandinii* they arise at a sharper angle and are more arched; the midvein in *A. serlii* extends almost to the apex of the pinnule, whereas in *A. grandinii* the midvein does not reach the apex. The terminal pinnules in *A. serlii* are lanceolate, whereas in *A. grandinii* they are long and narrow and have undulate margins. *Alethopteris serlii* is commonly found in association with *Neuropteris ovata* Hoffmann, *N. scheuchzeri* Hoffmann, and *Pecopteris lamuriana* Heer. *Alethopteris serlii* is a typical Westphalian C and D species but is more frequent in the Westphalian D.

DISTRIBUTION: In the United States, *Alethopteris serlii* is common in upper Pottsvillian and lower Alleghenian (Westphalian B, C, and D_1) strata, and very common in upper Alleghenian and lower Conemaughian (Westphalian D_2) strata and their equivalents in the central and Appalachian regions and in the Narragansett basin of New England. It is also very common in the Morien (Pictou) Group of Nova Scotia, Canada, and in the Minto Formation (Westphalian C and D) of New Brunswick, Canada. In Europe, this species is common in the Westphalian A, B, and C, but is most common in the Westphalian D.

SPECIMENS: WPMM F700, F701.

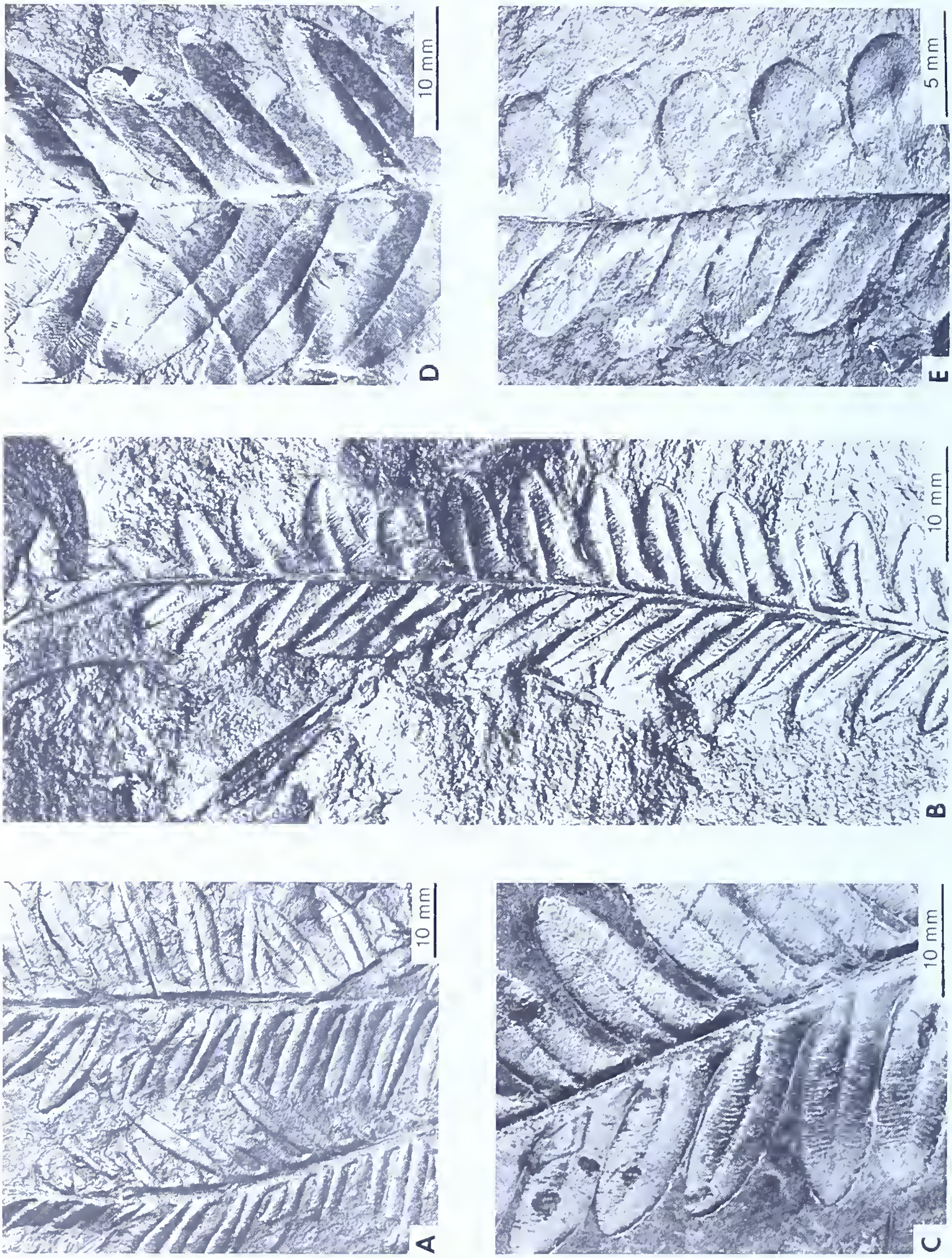
LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Alethopteris sullivantii (Lesquereux) Schimper, 1869
(Figure 20E, F)

Callipteris sullivantii Lesquereux, 1854, p. 423; 1858, p. 866, pl. 5, fig. 13.
Alethopteris sullivantii (Lesquereux). Schimper, 1869, p. 561.
Callipteridium sullivantii (Lesquereux). Weiss, 1870, p. 876, pl. 21, figs. 1-3.
Callipteridium sullivantii (Lesquereux) Weiss. White, 1899, p. 123, pl. 39, figs. 1-3; pl. 41, figs. 1-3.
Alethopteris sullivantii (Lesquereux) Schimper. Darrah, 1970, p. 114, pl. 4, figs. 1, 3.

DESCRIPTION: The specimens represent a few fragments of ultimate pinnae that have strong, longitudinally striated rachises to which the pinnules are attached. The pinnules are coriaceous and lingulate; they are contracted and often decurrent at the base. The midvein of the pinnules is distinct and strong for more than two thirds of the pinnule length, after which it repeatedly branches into veinlets which extend to the very obtuse apex of the pinnule. The lateral veinlets are fine, close, and forked two or often even three times; they arch toward the margin. Subsidiary veinlets are present in the decurrent base of the pinnule.

REMARKS: Young pinnae of *Alethopteris sullivantii* are odontopteroid in form as evidenced by the venation originating directly from the rachis. For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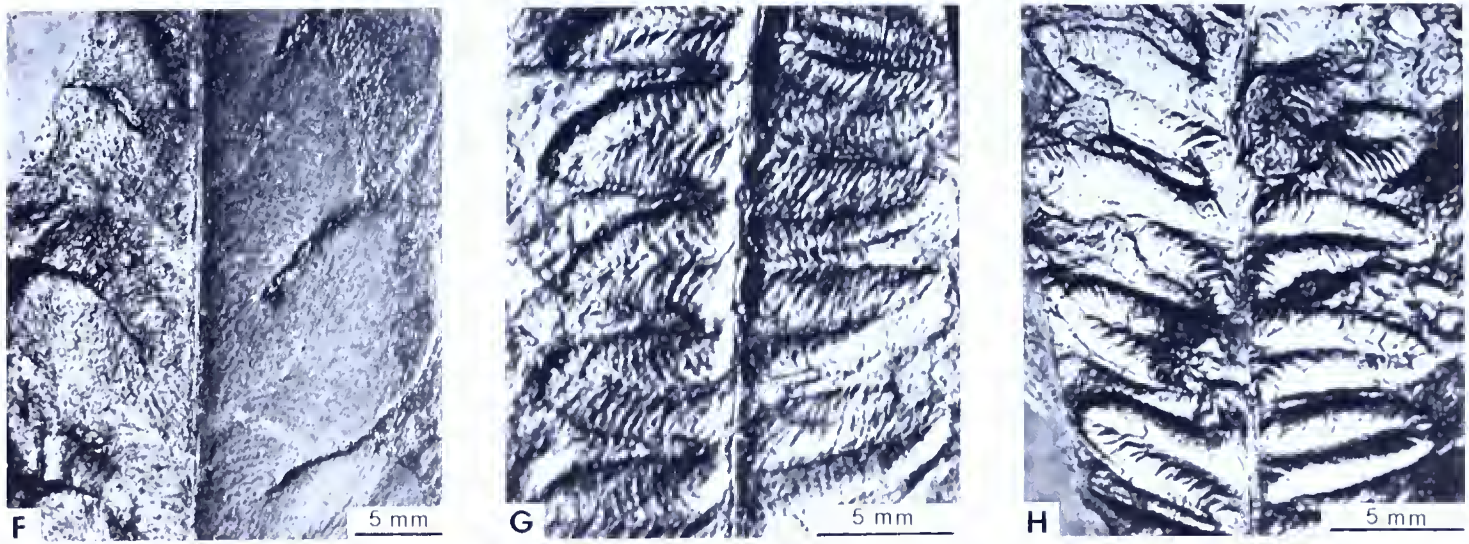


Figure 20. A, B, C, D. *Alethopteris serlii* (Brongniart) Goeppert [WPMM F701]; E, F. *Alethopteris sullivantii* (Lesquereux) Schimper [WPMM F623, F663]; G, H. *Alethopteris valida* Boulay [WPMM F649].

this reason Weiss (1870), in his studies on *Odontopteris*, associated *A. sullivantii* with *Callipteridium sullivantii*.

DISTRIBUTION: *Alethopteris sullivantii* is an excellent index fossil for Alleghenian (Westphalian D) strata and their equivalents in the central and Appalachian regions of the United States. This species is not known in either Pottsvillian or upper Conemaughian strata. In Europe, the species is known from Westphalian D deposits.

SPECIMENS: WPMM F623, F663.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Alethopteris valida Boulay, 1876
(Figure 20G, H)

Alethopteris valida Boulay, 1876, p. 35, pl. 1, fig. 2.
Alethopteris valida Boulay. Zeiller, 1886, pl. 23, figs. 1, 2; pl. 34, fig. 1; 1888, p. 231.
Alethopteris valida Boulay. Bell, 1938, p. 68, pl. 64, figs. 1-3; pl. 67, fig. 1.
Alethopteris valida Boulay. Novik, 1954, p. 85, pl. 19, figs. 8, 9; chart II.
Alethopteris valida Boulay. Gothan and Remy, 1957, p. 120, 121, 123, 214, fig. 114; chart 5.

DESCRIPTION: The pinnae in the illustrated specimen are large; the rachis is flexuous, longitudinally striated, and covered with minute punctae. The lower validopterid pinnules are large, elongate, lobate on their margins, about 25 mm in length and 5 mm in width, alternate, opposite or subopposite and oblique to the rachis, free at the base, and contracted to a narrowly rounded apex. The pinnules in the upper portion of the pinna are entire and alethopteroid, 8 to 9 mm in length and 3 mm in width, more or less oblique to the rachis, decurrent, and united near their bases; they taper toward the bluntly pointed apices.

Venation consists of a midrib which on the lower validopterid pinnules is as a thick cord, extending almost to the apex of the pinnule. Lateral veinlets arise from the midrib at an angle of about 45 degrees and usually divide twice; the first division occurs near the midrib and the second at about halfway between the midrib and the margin of the pinnule, slightly curving outward to meet the margin of the pinnule at an oblique angle. Some subsidiary veins enter the pinnule directly from the rachis of the pinna. The relatively long terminal pinnules of *A. valida*, which have undulating or slightly lobed margins and pointed apices, resemble the normal pinnules of *A. decurrens*. The midrib of the terminal pinnule of *A. valida* is weaker than the midribs of the pinnules in the lower (older) portions of the pinnae. The lateral veinlets in *A. valida* usually divide twice, and in *A. decurrens* they are often simple.

REMARKS: *Alethopteris valida* differs from *A. decurrens* mainly in the venation. In *A. valida* the lateral veinlets arise from the midrib at an angle of about 45 degrees, usually divide twice, take an oblique course, and meet the margin of the pinnule at an angle of 45 to 80 degrees. In *A. decurrens* the lateral veinlets arise from the midrib and meet the margin of the pinnule approximately at right angles, and the veinlets are often simple. The differences between *A. valida* and *A. serlii* (Brongniart) Goeppert are that the sinus separating adjacent pinnules is rounded in the former species and sharp in *A. serlii*; and the lateral veinlets are thicker, more distant, more divided, and oblique in *A. valida*, whereas in *A. serlii* the lateral veinlets arise from the midrib and meet the margin of the pinnule almost at right angles.

DISTRIBUTION: *Alethopteris valida* is a rare species in the United States. It is known only from the lower portion of the Llewellyn Formation (lower Alleghenian; Westphalian D) in the Northern Anthracite coal basin of Pennsylvania, and from the *Linopteris obliqua* Zone (Westphalian D) and *Ptychocarpus unitus* Zone (Westphalian D) of the Morien (Pictou) Group in the Sydney coal field in Nova Scotia, Canada. In Europe, this species is almost entirely confined to the Westphalian A and B, rarely occurring in the Westphalian C and D.

SPECIMEN: WPMM F649.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Family NEUROPTERIDACEAE

Genus *Neuropteris* Brongniart, 1822

Neuropteris decipiens Lesquereux, 1880

(Figure 24A)

Neuropteris decipiens Lesquereux, 1880, p. 93; 1884, p. 733, pl. 94, figs. 1, 2.

Neuropteris decipiens Lesquereux. Noé, 1925, p. 66, 68, 70, 72, 74, pl. 24, figs. 2-4; pl. 25; pl. 26; pl. 27, figs. 1, 2; pl. 28, figs. 2, 5.

Neuropteris decipiens Lesquereux. Darrah, 1970, p. 94, pl. 1, figs. 1-4; pl. 2, fig. 3; pl. 3, fig. 2; pl. 5, figs. 1, 2; pl. 6, fig. 2; pl. 8, figs. 1-3; pl. 46, fig. 3; pl. 76, fig. 1.

DESCRIPTION: This species is represented only by detached large, elongate pinnules and small, orbicular basal pinnules. The large, elongate pinnules are cordate at the base and commonly narrow gradually to an obtuse, rarely acuminate apex. The midvein extends nearly to the apex; fine lateral veinlets dichotomize usually four times. Rigid hairs, 1.5 to 3 mm long, are scattered mainly on the lower surface of both the large, elongated pinnules and the small, orbicular basal pinnules.

REMARKS: *Neuropteris decipiens* is distinguished from *N. scheuchzeri* Hoffmann by the greater size of the elongated pinnules, which have a cordate base and stiff hairs, by the stronger midvein near the base, by the slightly more distant and coarse lateral veinlets (about 24 to 30 per cm on the margins of pinnules), and by the more varied odontopteroid pinnules. Kidston (1886), White (1893), and Crookall (1959) consider *N. decipiens* a robust variety of *N. scheuchzeri*. Darrah (1970) considers *N. decipiens* a local species derived from *N. scheuchzeri.*

DISTRIBUTION: *Neuropteris decipiens* is known from lower Carbondale strata of the Mazon Creek region, Illinois, and from Alleghenian (Westphalian D) strata in the Appalachian region in the United States.

SPECIMEN: WPMM F689.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Neuropteris heterophylla Brongniart, 1822
(Figure 21C)

Filicites (Sect. *Nevropteris*) *heterophylla* Brongniart, 1822, p. 33, 239, pl. 2, fig. 6.

Nevropteris heterophylla Brongniart, 1828a, p. 243, pl. 71; pl. 72, fig. 2; 1828b, p. 53, 169.

Imparipteris (Neuropteris) heterophylla Brongniart. Gothan and Remy, 1957, p. 124, 133, 189, 218, figs. 118, 119, 218; chart 5.

Neuropteris heterophylla Brongniart. Crookall, 1959, p. 92, 96, pl. 25, figs. 1-3; pl. 26; pl. 27, figs. 1-5; pl. 28, figs. 1-5; pl. 29, fig. 5; pl. 32, figs. 1, 2; pl. 49, fig. 7; pl. 54, fig. 2; pl. 55, figs. 1, 2; text-figs. 33-35, 63e, h, l. (Contains a more complete synonymy.)

Neuropteris heterophylla Brongniart. Darrah, 1970, p. 98.

Neuropteris heterophylla Brongniart. Oleksyshyn, 1976, p. 164, fig. 10B.

DESCRIPTION: The specimens represent only tertiary pinnae. The pinnae are long and narrow and have flexuous, longitudinally striated rachises. The pinnules have oval or oval-elliptical outlines and more or less cordate bases; they are alternate or subopposite, usually contiguous, and either sessile or attached by a single point to the rachis. Near the apex, the pinnae are more or less united to the rachis and slightly odontopteroid; the terminal pinnule is rhomboidal and larger than the lateral pinnules.

Venation in the oval pinnules consists of a well-marked median vein that extends two thirds the length of the pinnule, and fine lateral veinlets, which arise from the median vein at a sharp angle. The lateral veinlets are oblique, divide twice, or, in some cases, three times, and arch toward the margin. In oval-elliptical pinnules the median vein is less strong and the lateral veinlets arise from the median vein at an acute angle and divide once or twice, except in the terminal pinnule, where the lateral veinlets usually arise directly from the rachis.

REMARKS: *Neuropteris heterophylla* has some resemblance to *N. tenuifolia* (Schlotheim) Sternberg, but the pinnules of the former are shorter in proportion to their breadth; the terminal pinnules are generally broader and the lateral veinlets are stronger and fewer than those of *N. tenuifolia*.

DISTRIBUTION: In the United States, *Neuropteris heterophylla* is a common species in the upper Pottsvillian and lower Alleghenian (Westphalian B_2 and C), and is rare in the upper Alleghenian (lower Westphalian D) in the central and Appalachian regions and in the Narragansett basin of New England. It is also found in the Pictou Group of New Brunswick, and in the Morien (Pictou) Group (Westphalian C and lower D) in the Sydney coal field, Nova Scotia, Canada. In Europe, this species is common in the Westphalian A, very common in the Westphalian B, rather rare in the Westphalian C, and very rare in the Westphalian D.

SPECIMEN: WPMM F661.

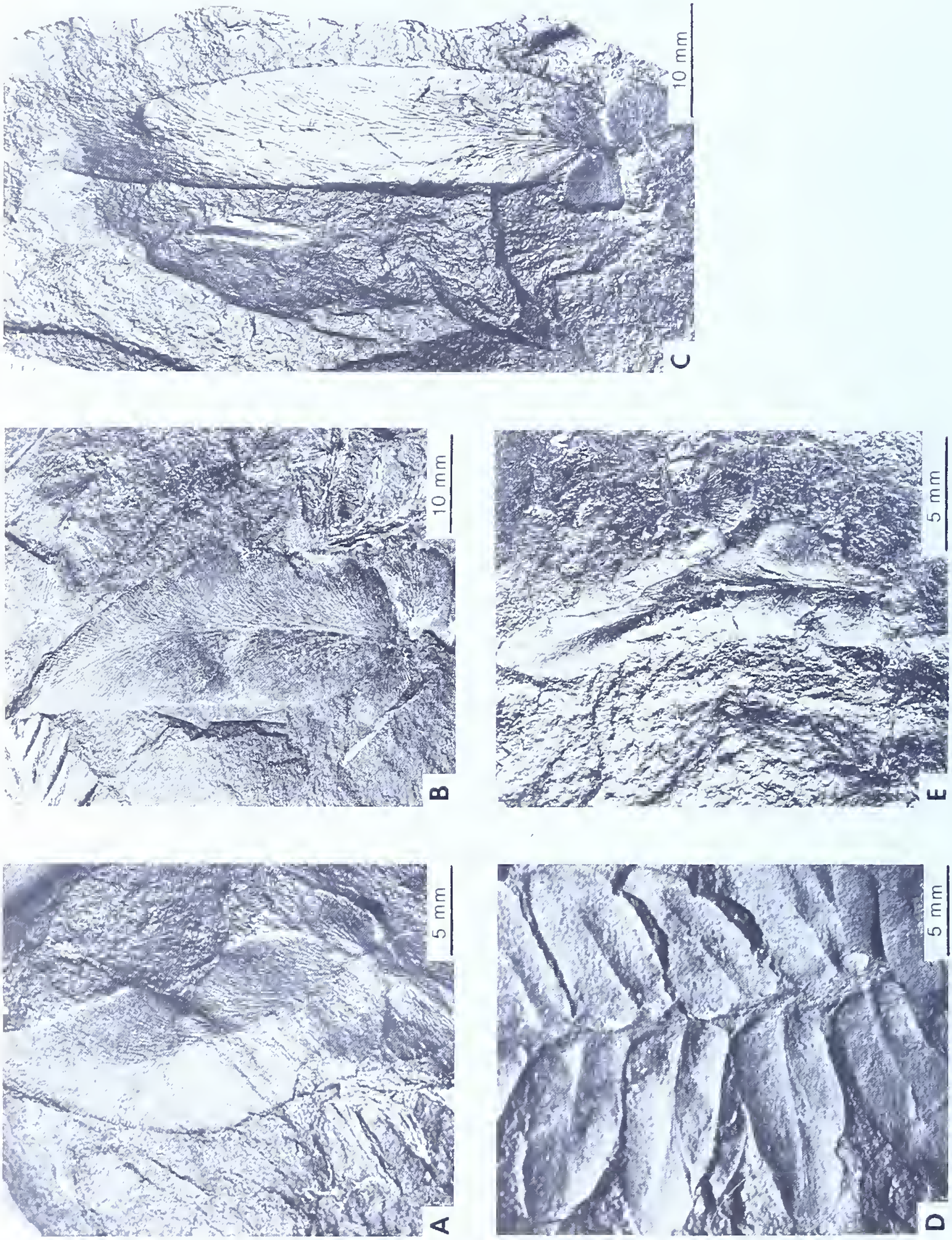
LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Neuropteris macrophylla Brongniart, 1828a
(Figure 21A, B, D)

Nevropteris macrophylla Brongniart, 1828a, p. 235, pl. 65, fig. 1.
Neuropteris clarksoni Lesquereux, 1879, pl. 9, figs. 1-6; 1880, p. 94.
Neuropteris macrophylla Brongniart. Bell, 1938, p. 60, pl. 54, fig. 5; pl. 55, figs. 2-4.
Neuropteris macrophylla Brongniart. Crookall, 1959, p. 176, pl. 38, fig. 4; pl. 39, fig. 1; pl. 40, figs. 1-3; pl. 42, figs. 1, 3; text-figs. 67B, C. (Contains a more complete synonymy.)

DESCRIPTION: The illustrated specimen is only a fragment of a pinna that has a few pinnules alternately attached to a flexuous, longitudinally striated rachis. The pinnules vary in size and shape; they are lanceolate-acute, oblong-obtuse, or cordate or auricled at the base, the lower auricle usually much more pronounced than the upper. The terminal pinnule is lanceolate.

The midvein is distinct, especially at the base; it thins gradually toward the middle of the pinnule. The numerous strong lateral veinlets arise at an acute angle and are arched. Some of the veinlets dichotomize twice; most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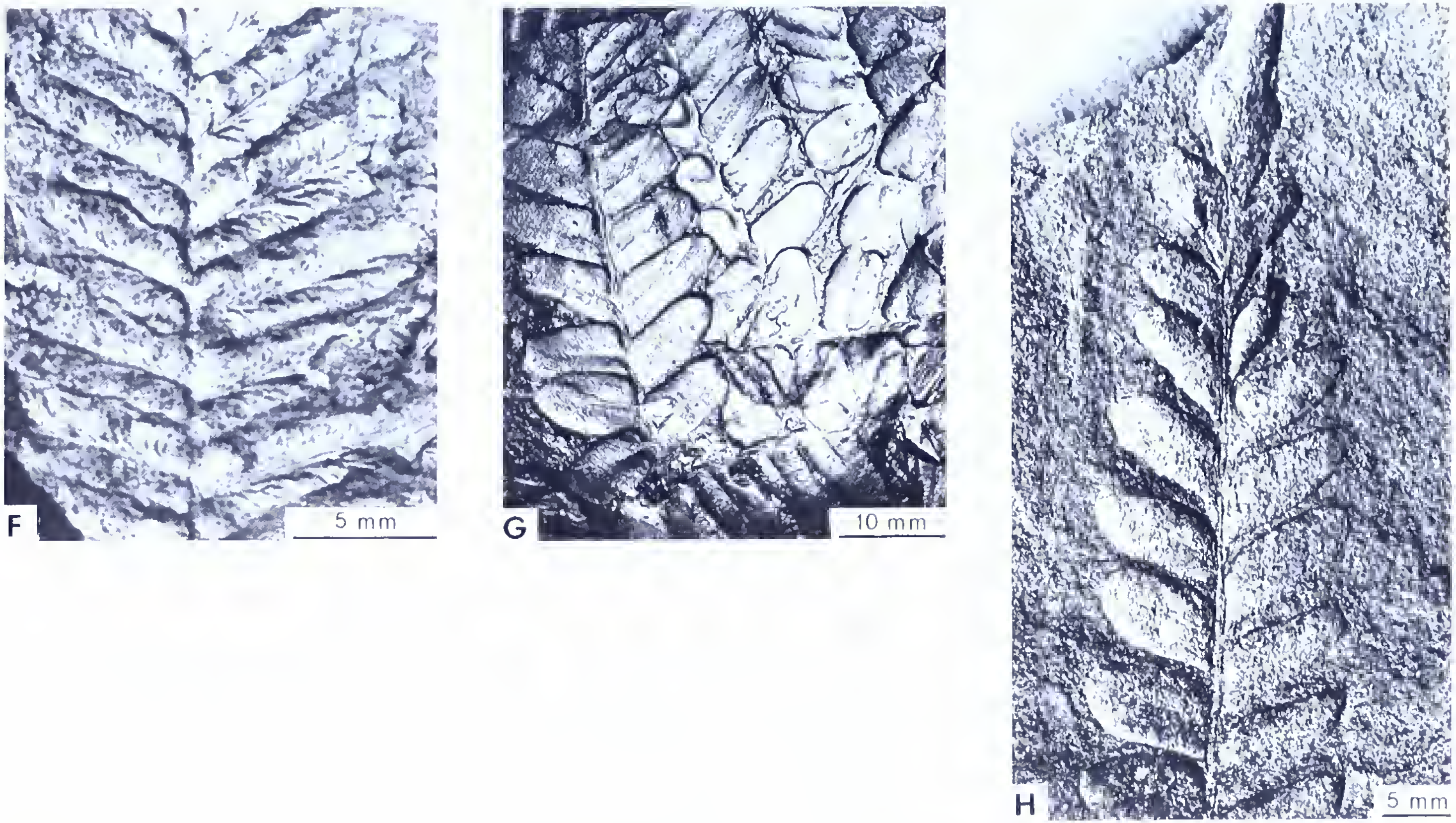


Figure 21. A, B, D. *Neuropteris macrophylla* Brongniart [WPMM F692, F693, F565]; C. *Neuropteris heterophylla* Brongniart [WPMM F661]; E. F. *Neuropteris obliqua* (Brongniart) Goeppert [WPMM F667]; G, H. *Neuropteris ovata* Hoffmann forma *typica* [WPMM F691].

dichotomize four times, and a few, five times, the last fork being near the margin of the pinnule. About 35 perpendicular veinlets per centimeter meet the margin of the pinnule.

REMARKS: The similarity of certain pinnules of *N. macrophylla* to those of *N. scheuchzeri* Hoffmann often causes misidentification of these species. The main difference between them is the shape of the basal parts of the pinnules and the villosity. The auricles at the base of the pinnules of *N. macrophylla* are unequilateral, whereas the auricles of the pinnules of *N. scheuchzeri* are more equal. The hairs on the lower side of the pinnules of *N. scheuchzeri* are much longer and more numerous. *N. ovata* Hoffmann forma *flexuosa* Sternberg may be distinguished from *N. macrophylla* by the following characteristics: (1) its pinnules are typically broader in relation to their length; (2) the lower basal angle is much less developed and does not overlap the rachis; and (3) there is no strong midvein, and the lateral veinlets are more distant and more flexuous than those of *N. macrophylla*.

DISTRIBUTION: In the United States, *Neuropteris macrophylla* is known from Alleghenian strata in the Appalachian region and from equivalent strata (Westphalian C and lower D) in the Mazon Creek-Wilmington region of Illinois. It is also known from the Morien (Pictou) Group in the Sydney coal field of Nova Scotia, Canada. In Europe, this species ranges from Westphalian B to D, but it is most common in the Westphalian D.

SPECIMENS: WPMM F565, F692, F693.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Neuropteris obliqua (Brongniart) Goeppert, 1841
(Figure 21E, F)

Pecopteris obliqua Brongniart, 1828a, p. 320, pl. 96, figs. 1-4; 1828b, p. 57, 170.

Neuropteris obliqua Brongniart. Goeppert, 1841, p. 3, 6, pl. 11, fig. 1.

Neuropteris obliqua (Brongniart). Zeiller, 1886, pl. 48, figs. 1, 2, 4-7; 1888, p. 284.

Imparipteris (Neuropteris) obliqua (Brongniart) Zeiller. Gothan and Remy, 1957, p. 129, 133, 189, 216, figs. 125-127; chart 5.

Neuropteris obliqua Brongniart. Crookall, 1959, p. 165, pl. 42, fig. 2; pl. 45, figs. 1, 2; pl. 46, figs. 1-4; pl. 47, fig. 4; pl. 56, figs. 1-4; pl. 57, fig. 4; pl. 58, figs. 4, 5; text-figs. 53-55, 62b, c, e, f, 64d, e, f, 65e. (Contains a more complete synonymy.)

Neuropteris obliqua Brongniart. Lyons and others, 1976, figs. 4A-H, 5A-C.

DESCRIPTION: The primary pinnae of the specimens are lanceolate and taper toward the apex; they are bipinnate for most of their length, but unipinnate at the apex. The rachis is flexuous and has fine longitudinal striae. The secondary pinnae are alternate and narrowly triangular. The pinnules are subopposite, slightly distant, and often slightly falcate; they have rounded apices. Near the apex of the secondary pinnae, the pinnules are ovate or linear-lanceolate, and are attached by a broad base. The terminal pinnule is about twice as long as the adjacent lateral pinnules, is narrowly lanceolate, and has a rounded apex. The midvein is relatively thin and can be traced for a distance of from two thirds to three quarters the length of the pinnule. The lateral veinlets are distinct, fine, and distant near the midvein; they arch and divide two or three times, and are very closely spaced near the margin of the pinnule. Some subsidiary veinlets enter the base of the pinnule directly from the rachis.

REMARKS: *Neuropteris obliqua* has some similarity to *N. ovata* Hoffmann, especially in the frequently strongly odontopteroid development of the apical portion of the secondary pinnae. The main difference between these two closely allied species is that the lateral veinlets in *N. ovata* are closer and less distinct than in *N. obliqua*. The venation also helps to distinguish *N. obliqua* from *N. heterophylla* Brongniart; the lateral veinlets of *N. obliqua* are more distinct and more flexuous than those of *N. heterophylla*. The terminal pinnule of the secondary pinnae of *N. heterophylla* is much longer than that of *N. obliqua*.

DISTRIBUTION: *Neuropteris obliqua* is known from upper Pottsvillian and Alleghenian strata and their equivalents (Westphalian B, C, and lower D) in the central and Appalachian regions in the United States, and from the Cumberland Group (Westphalian B) of New Brunswick and Nova Scotia, Canada. In Europe, this species is known from the entire Westphalian, but it is most common in the Westphalian B.

SPECIMENS: WPMM F667, F724.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

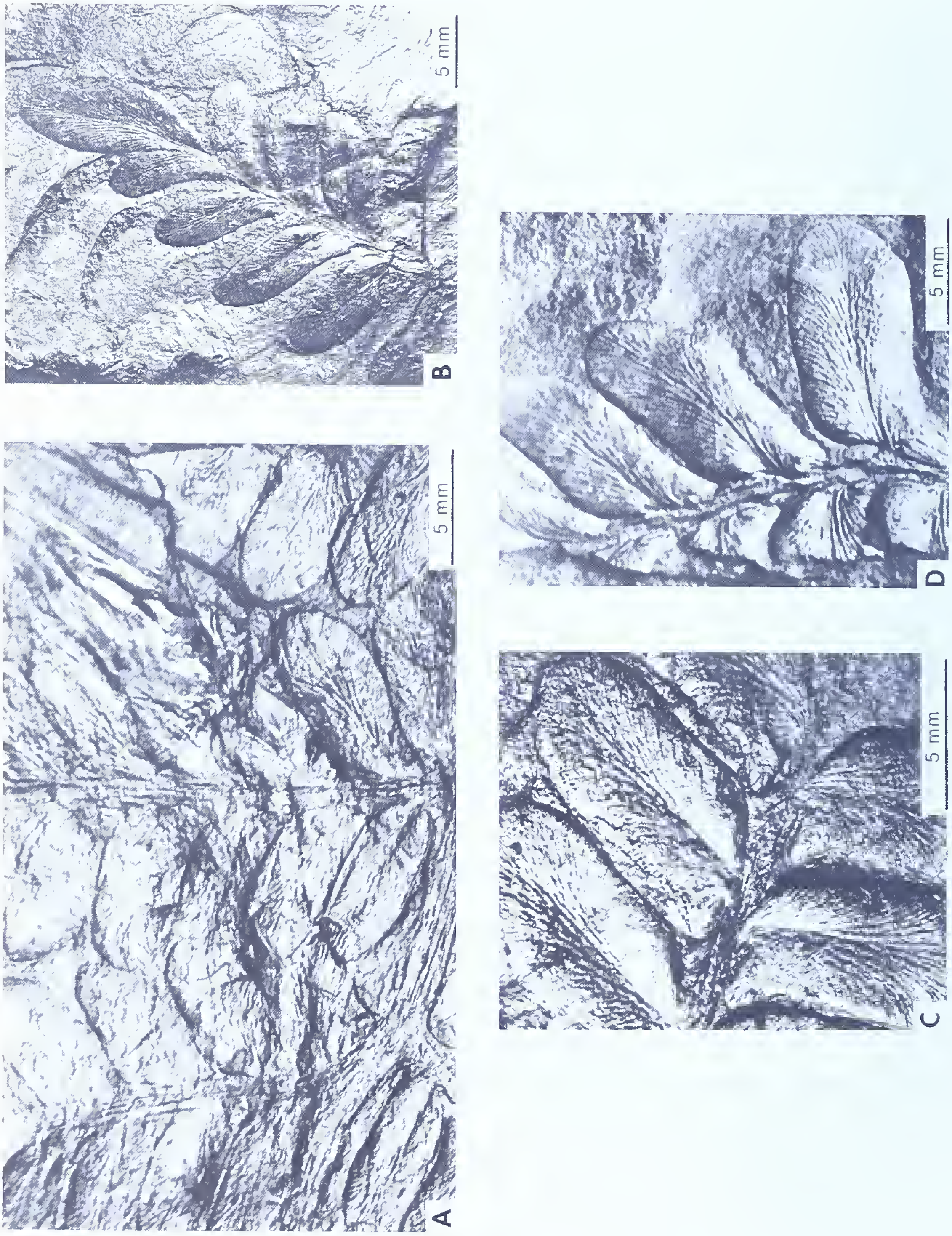
Neuropteris ovata Hoffmann forma *typica*, 1826
(Figures 21G, H; 22A, B, C, D, E, F, G; 25C, D, E)

Neuropteris ovata Hoffmann, 1826, p. 158, pl. 16, figs. 5-8.

Neuropteris ovata Hoffmann. Noé, 1925, p. 58, 60, pl. 20, fig. 3; pl. 21, fig. 4.

Neuropteris ovata Hoffmann. Bell, 1938, p. 60, pl. 52, fig. 4; pl. 53, fig. 3; pl. 54, figs. 1-3.

Neuropteris ovata Hoffmann forma *typica*. Crookall, 1959, p. 149, 153, pl. 33, figs. 3-6; pl. 43, figs. 1-5; text-figs. 49, 50, 51, 66F. (Contains a more complete synonymy.)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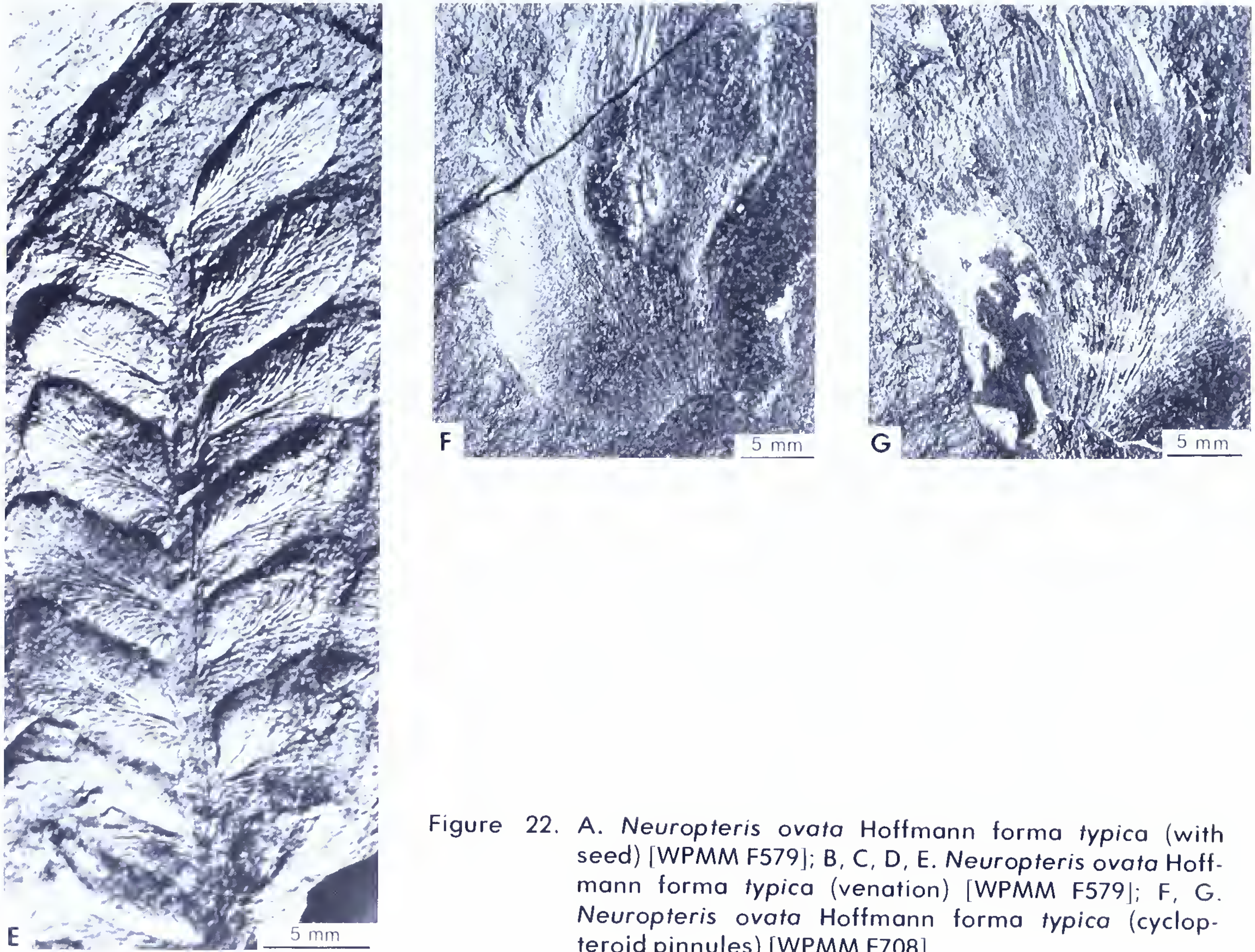


Figure 22. A. *Neuropteris ovata* Hoffmann forma *typica* (with seed) [WPMM F579]; B, C, D, E. *Neuropteris ovata* Hoffmann forma *typica* (venation) [WPMM F579]; F, G. *Neuropteris ovata* Hoffmann forma *typica* (cyclopteroid pinnules) [WPMM F708].

Neuropteris ovata Hoffmann forma *typica*. Darrah, 1970, p. 105, pl. 9, fig. 2; pl. 10, figs. 1, 2.

DESCRIPTION: The species is represented by a large and tripinnate frond; the secondary pinnae are subopposite, gently tapering, and imparipinnate (having one terminal pinnule). The pinnules are sessile or attached by a very small stalk to a longitudinally striated rachis; they are comparatively small, ovate or oblong, and approximately twice as long as broad, ranging from 8 to 18 mm in length and 4 to 8 mm in breadth. The base of each pinnule is more or less cordate, and the apex is broadly rounded. The terminal pinnule is relatively small, averaging about 16 mm in length by 7 mm in breadth, more or less lanceolate, and generally confluent with the uppermost lateral pinnules. The midvein usually disappears below the middle; in some specimens it is obscured by branching and dividing. Fine lateral veinlets extend to the margins of the pinnules.

REMARKS: *Neuropteris ovata* forma *typica* has many minor variations in form, size, and spacing of its pinnules. It is very often confused with *N. ovata* Hoffmann forma *flexuosa* Sternberg, *N. tenuifolia* (Schlotheim) Sternberg, *N. obliqua* (Brongniart), *N. gigantea* Sternberg, and some others. One example of such misidentification is *N. loschii* Lesquereux, which is *N. ovata* forma *typica*.

DISTRIBUTION: In the central and Appalachian regions of the United States, *Neuropteris ovata* forma *typica* rarely occurs in the upper Pottsvillian (Westphalian B_2); it is more common in the Alleghenian (Westphalian C and lower D), very abundant in the lower Conemaughian (Westphalian uppermost D_2 and Stephanian A), less common in the upper Conemaughian, and not present in the lower Monongahelan (Stephanian B). This species is also known from the Morien (Pictou) Group of the Sydney coal field in Nova Scotia, Canada. In Europe, the species is rare in the Westphalian A and B, fairly common in the Westphalian C, and very common in the Westphalian D; in northwestern Spain it extends to the Stephanian B (Wagner, 1964).

SPECIMENS: WPMM F579, F691, F708, F725a, F728b, F723.

LOCALITIES: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed; and Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Neuropteris ovata Hoffmann forma *flexuosa* Sternberg, 1823

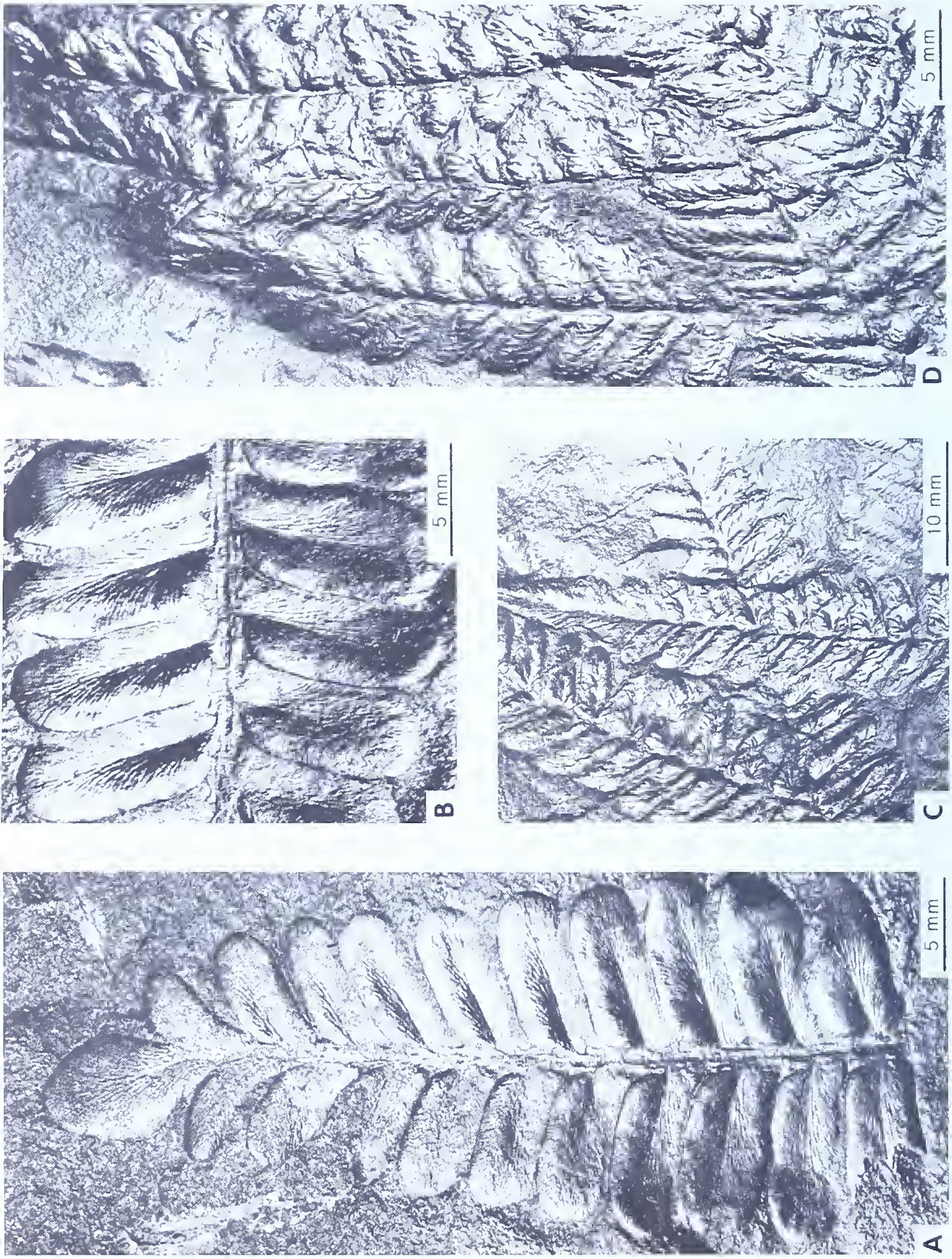
(Figure 23A, B)

Neuropteris flexuosa Sternberg, 1823, p. 36, 39, pl. 32, fig. 2; 1838, p. 16.

Neuropteris flexuosa Sternberg. Brongniart, 1828a, p. 239, pl. 65, figs. 2, 3; pl. 68, fig. 2, 2A; 1828b, p. 53, 169.
Neuropteris plicata Sternberg. Lesquereux, 1879, pl. 10, figs. 1-4; 1880, p. 96.
Neuropteris (Mixoneura) flexuosa Sternberg. Bell, 1938, p. 55, pl. 56, figs. 6, 7; pl. 67, figs. 1-3; pl. 68, fig. 2.
Neuropteris ovata Hoffmann forma *flexuosa* (Sternberg). Crookall, 1959, p. 158, pl. 37, figs. 1-3; pl. 38, figs. 1-3; pl. 49, figs. 5, 6; pl. 50, figs. 3-5; text-figs. 52, 62j, 66j. (Contains a more complete synonymy.)
Neuropteris ovata forma *flexuosa* Sternberg. Darrah, 1970, p. 106, pl. 73, fig. 1.

DESCRIPTION: The secondary pinnae of the figured specimen taper gently and are imparipinnate. The pinnules are relatively large, oblong, approximately three times longer than broad at the base, and alternately and somewhat obliquely attached to a flexuous, longitudinally striated rachis. The base of each pinnule is only slightly cordate; the upper basal margin is rounded and the lower basal margin is auricled. The apex of each pinnule is obtuse. Venation is fairly fine but distinct; the midvein is less prominent and evident only to one half to two fifths of the length of the pinnule. The lateral veinlets arise very obliquely, arch gently outward, divide usually four times, and produce about 40 ultimate veinlets per centimeter of margin length. The midvein leaves the relatively broad base of the pinnule attachment and is accompanied by lateral truck veinlets on both sides, a type of venation common to species assigned to *Mixoneura* (Bell, 1938).

REMARKS: *Neuropteris ovata* forma *flexuosa* is characterized by the possession of larger pinnules than *N. ovata* Hoffmann forma *typica*. The terminal pinnule is also larger and broader. In some pinnae odontopteroid pinnules are found. *Neuropteris ovata* forma *flexuosa* differs from *N. tenuifolia* (Schlotheim) Sternberg only in that its pinnules are larger and broader in proportion to their length, and taper less at the apex; also, the midvein is less prominent, and the lateral veinlets divide several times. The pinnules of *N. tenuifolia* are longer in proportion to their breadth and are slightly falcate; the midvein, situated nearer the lower border in the lower part of the pinnule, is straight and more prominent, and the lateral veinlets divide only once or twice. *Neuropteris ovata* forma *flexuosa* differs from *N. macrophylla* Brongniart mainly in the form of the pinnules, which in the latter species are lanceolate-acute or oblong-obtuse, are cordate or auriculate at the base, and often overlap the rachis. Also, the midvein of *N. macrophylla* is distinct, especially near the base, and thins toward the middle of the pinnule, giving rise to more distinct lateral veinlets which divide several times before reaching the margins. The main difference between *N. ovata* forma *flexuosa* and *N. heterophylla* is that the pinnules of the latter species are nearly ovate or oval-elliptical, and obtuse, having more or less cordate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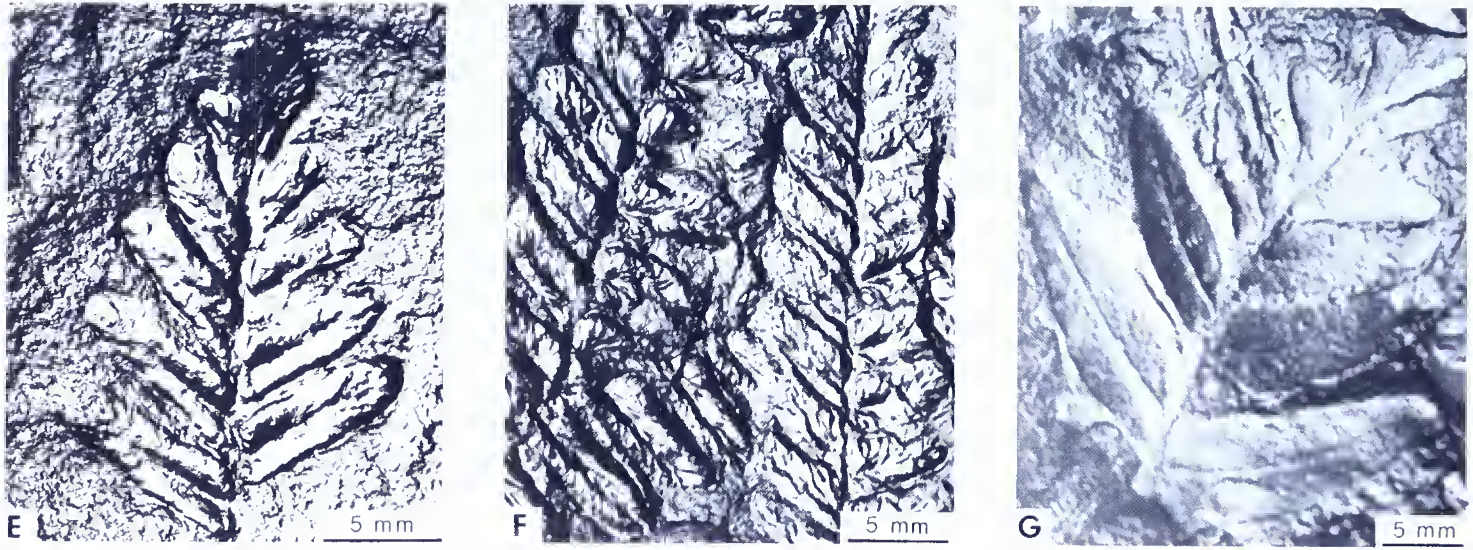


Figure 23. A, B. *Neuropteris ovata* Hoffmann forma *flexuosa* Sternberg [WPMM F574]; C, D, F. *Neuropteris rarinervis* Bunbury [WPMM F727a, F727b]; E. *Neuropteris rarinervis* Bunbury (tip of pinna) [WPMM F72]; G. *Neuropteris tenuifolia* (Schlotheim) Sternberg [WPMM F597].

bases; they are usually contiguous, sessile, or attached by a short pedicel to the rachis. The terminal pinnule is rhomboidal and much larger than the other pinnules. The midvein is flexuous in its upper part and is divided close to the apex. The lateral veinlets are strong and somewhat flexuous; they divide two to three times before reaching the margin of the pinnule.

DISTRIBUTION: In the central and Appalachian regions of the United States, the earlier traces of *N. ovata* forma *flexuosa* are known from the lower Alleghenian; it occurs sparingly in the middle Alleghenian, and is more abundant in the upper Alleghenian, Conemaughian, and lower Monongahelan. It is rarer in later strata (Westphalian D to Stephanian C), ranging to the upper Dunkardian. This species is also known from the Pictou Group of New Brunswick, Canada, and from the Morien (Pictou) Group of Nova Scotia, Canada. In Europe, the species is rare in the Westphalian A and B, fairly common in the Westphalian C, and very common in the Westphalian D.

SPECIMENS: WPMM F574, F725b, F726.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Neuropteris rarinervis Bunbury, 1847
(Figure 23C, D, E, F)

Neuropteris rarinervis Bunbury, 1847, p. 425, pl. 22.

Neuropteris rarinervis Bunbury. Lesquereux, 1879, pl. 15, figs. 2-5; 1880, p. 109.

Neuropteris rarinervis Bunbury. Bell, 1938, p. 58, pl. 52, fig. 3; pl. 53, figs. 1, 2; pl. 54, fig. 4.

Neuropteris rarinervis Bunbury. Crookall, 1959, p. 122, pl. 30, figs. 1-3; pl. 31, figs. 1-3; text-figs. 43, 44, 64G, H. (Contains a more complete synonymy.)

Neuropteris rarinervis Bunbury. Darrah, 1970, p. 101, pl. 20, fig. 2.

DESCRIPTION: The species is represented by a large frond, consisting only of secondary linear-lanceolate pinnae that are arched slightly forward; they are alternately or suboppositely attached either at right angles or obliquely to strong, undulating rachises. The pinnae are contiguous or overlap each other; they are contracted toward the apex and obtusely pointed. The pinnules are small, coriaceous, oblong to elliptical, averaging 8 mm long by 4 mm broad, and alternate or subopposite; they gradually narrow near the rounded apex, and are usually somewhat oblique to the straight or slightly flexuous, longitudinally striated rachis. The margins of the pinnules are slightly undulate, distant, or contiguous with each other; they are sessile or attached by a single point to the rachis, and are more or less cordate to auriculate at the base.

Venation is pronounced; the midvein is thick, especially at the base, and usually arises from nearer the posterior margin than the anterior margin. The midvein forms a furrow on the upper side of the pinnule, which is evident at least halfway up the pinnule, and often almost to the apex. The midvein bifurcates close to the apex. The lateral veinlets are thick, prominent, and distant; the basal veinlets divide close to the midvein and their upper arms divide once or twice. Succeeding lateral veinlets commonly bifurcate farther from the midvein, and the upper arm divides again, arching to the margin; those toward the summit of the pinnule are usually undivided.

REMARKS: *Neuropteris rarinervis* resembles some specimens of *N. heterophylla* Brongniart. The main difference between these two species is that *N. rarinervis* usually has smaller pinnules, and its lateral veinlets are fewer, thicker, less divided, more arched, and more distant than in *N. heterophylla*. In *N. schlehani* Stur the lateral veinlets are more numerous and much finer than in *N. rarinervis*. *Neuropteris coriacea* Lesquereux is probably a large form of *N. rarinervis* (Zeiller, 1886; Kidston, 1886).

DISTRIBUTION: *Neuropteris rarinervis* is known from upper Pottsvillian to middle Alleghenian (Westphalian B to Westphalian lower D) strata; the greatest abundance is in the Westphalian C and lower D in the central and Appalachian regions of the United States. It occurs in the Clifton Formation (Pictou Group) of New Brunswick, Canada, and in the Morien (Pictou) Group of Nova Scotia, Canada. In Europe, the species ranges from the Westphalian B to D; it is very rare in the Westphalian B and common in both the Westphalian C and D.

SPECIMENS: WPMM F721, F727a, F727b.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Neuropteris scheuchzeri Hoffmann, 1826
(Figures 24B, C, D, E, F; 25A, B)

Neuropteris scheuchzeri Hoffmann, 1826, p. 156, pl. 1b, figs. 1-4.

Neuropteris scheuchzeri Hoffmann. Brongniart, 1828a, p. 230, pl. 63, fig. 5.

Neuropteris scheuchzeri Hoffmann. White, 1899, p. 132, pl. 37, fig. 4; pl. 42, fig. 3; pl. 64, fig. d.

Neuropteris scheuchzeri Hoffmann. Bell, 1938, p. 57, pl. 50. figs. 3, 4; pl. 51, figs. 1-5; pl. 52, figs. 1, 2.

Neuropteris scheuchzeri Hoffmann. Crookall, 1959, p. 178, pl. 41, figs. 1, 2; pl. 42, figs. 4-7; pl. 57, figs. 1, 2, 5; text-figs. 57-59, 65A, B, D. (Contains a more complete synonymy.)

DESCRIPTION: *Neuropteris scheuchzeri* is a polymorphous species represented by different types of pinnules. The most common are large, elongate pinnules that are slightly constricted at the base and taper to a bluntly or sharply pointed apex. Near the lower third of the leaflet, some pinnules reach 10 cm in length and 2.5 cm in width. Such pinnules are often accompanied by two small orbicular cyclopteroid basal pinnules, but some of the latter may have fallen away, giving the appearance of a single intercalary pinnule. Large pinnules are entire or undulate, and are often somewhat falcate. Still other pinnules, less common than the others, are cyclopteroid, squat, rounded, or occasionally lobate, approximately one and one half times longer than broad.

A fine midvein extends nearly to the apex of the pinnule and gives rise to numerous oblique lateral veins, which usually divide four times, or, rarely, five times. The first dichotomy is near the midvein, the second and the third dichotomies are about midway to the margin of the pinnule, and the fourth dichotomy occurs near the margin. The number of veinlets at the margin of the pinnule is about 40 per centimeter of length. The venation of cyclopteroid basal pinnules of the trifolial pinnae usually is flabellate from the base and slightly coarser than that in the terminal, large, elongated pinnules. The venation of squat, rounded, occasionally lobate pinnules is coarse and flabellate (fanlike) from the base. The cyclopteroid pinnules often split into tread-like structures near their distal margins.

Important characteristics of this species are the scattered, rigid hairs up to 2 mm in length that are usually oblique to the lateral veinlets, mainly on the lower surface of the large, elongate pinnules (Figure 25A, B).

REMARKS: The most common fossil remains of *N. scheuchzeri* are detached single, large, elongate pinnules and small, orbicular, cyclopteroid basal pinnules of trifoliate pinnae. The presence of rigid hairs, especially on the lower surface of large pinnules of *N. scheuchzeri*, and their absence or very scanty occurrence on the upper surface led Lesquereux to recognize two species: *N. hirsuta*, whose pinnules have a villous lower surface, and *N. angustifolia*, whose pinnules do not have rigid hairs on the upper surface. White (1899) found that the hirsuteness occurs in both species reported from the same localities, and that, therefore, there was no basis for creating two species.

DISTRIBUTION: *Neuropteris scheuchzeri* is relatively rare in upper Pottsvillian and lower Alleghenian (Westphalian B_2 and C) strata, but becomes abundant in upper Alleghenian, Conemaughian, Monongahelan, and Dunkardian rocks (Westphalian D and Stephanian A, B, and C) in the central and Appalachian regions of the United States. It is also known from the

Minto Formation (Pictou Group) of New Brunswick, Canada, and from the Morien (Pictou) Group (Westphalian C and D) of Nova Scotia, Canada. In Europe, this species is extremely rare in the Westphalian A, very rare in the Westphalian B, and very abundant in the Westphalian C and D; in northwestern Spain the species extends into the Stephanian A (Wagner, 1964).

SPECIMENS: WPMM F580, F655, F719, F720, F722, F728a.

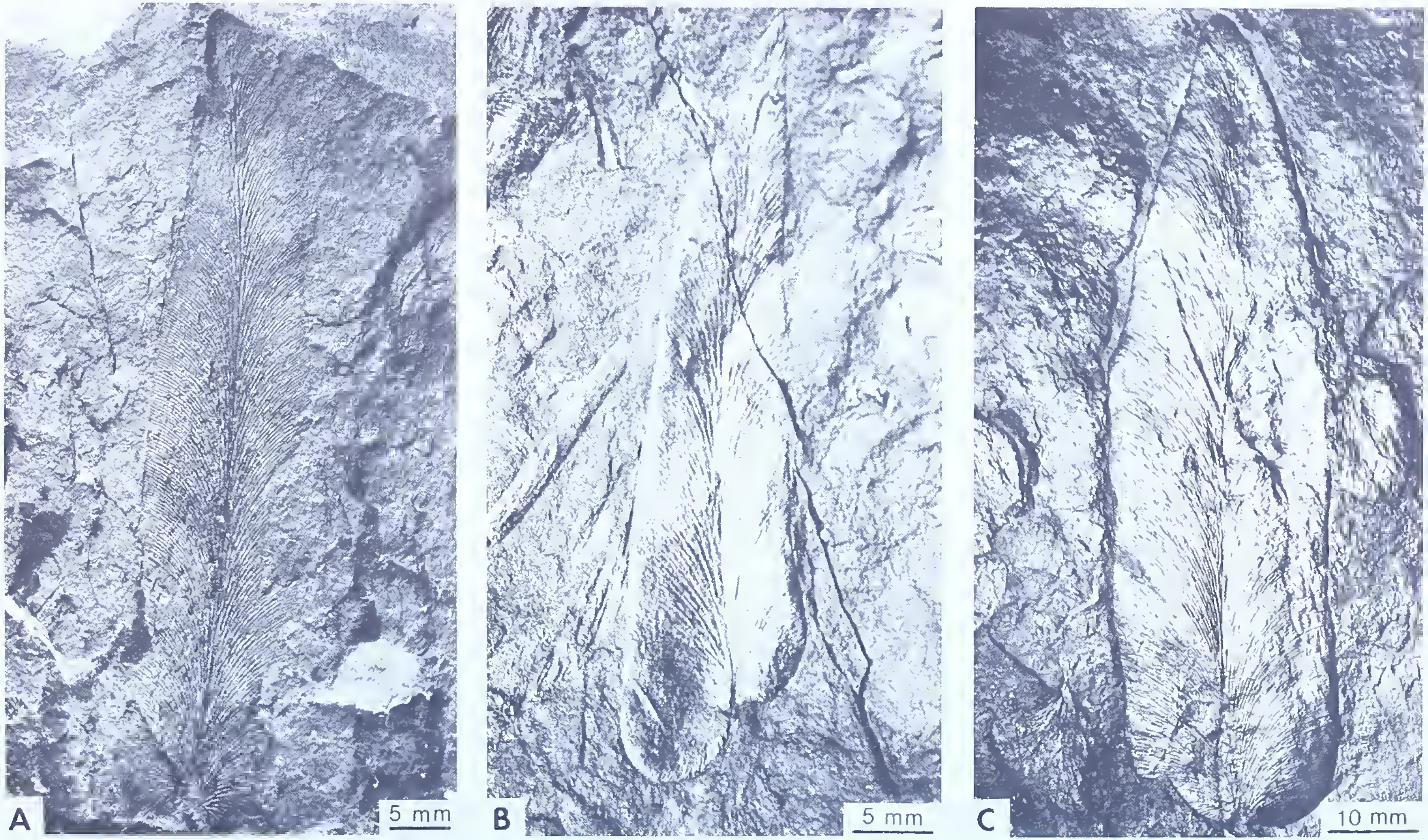
LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Neuropteris tenuifolia (Schlotheim) Sternberg, 1825
(Figure 23G)

Filicites tenuifolius Schlotheim. 1820, p. 405, pl. 22, fig. 1.
Nevropteris tenuifolia Schlotheim. Sternberg, 1825, p. 17; 1833, p. 72.
Nevropteris tenuifolia Brongniart, 1828a, p. 241, pl. 72, fig. 3; 1828b, p. 53, 169.
Neuropteris tenuifolia Brongniart. Lesquereux, 1879, pl. 12, figs. 4-7; 1880, p. 100.
Neuropteris tenuifolia (Schlotheim). Bell, 1938, p. 54, pl. 46, figs. 1-5.
Neuropteris tenuifolia Schlotheim. Crookall, 1959, p. 117, pl. 29, figs. 1-4; text-figs. 42, 63F, K. (Contains a more complete synonymy.)

DESCRIPTION: Specimens of this species represent separate pinnae having flexuous, longitudinally striated rachises. The pinnules are alternate or subopposite and elongate; they converge slightly toward their rounded or obtuse apices. Some pinnules are slightly falcate, and more or less cordate at the base; most pinnules are attached by a single point or are sessile. Pinnules situated near the terminal pinnule are slightly longer than the other pinnules, are attached by the whole base, and are cyclopteroid. The midvein is straight or slightly curved, and strong at the base; it extends approximately two thirds of the length of the pinnule. Lateral veinlets are thin but distinct; they arise from the midvein at a sharp angle, divide two or three times, and in longer pinnules four times, arch, and meet the margin of the pinnule at an oblique angle. No terminal pinnule was found.

REMARKS: *Neuropteris tenuifolia* has some similarity to *N. heterophylla* Brongniart, *N. ovata* Hoffmann forma *flexuosa* Sternberg, and *N. rarinervis* Bunbury. The difference between *N. tenuifolia* and *N. heterophylla* is mainly in the size, shape, and venation of the pinnules. The pinnules of *N. tenuifolia* are longer in proportion to their breadth; the lateral veinlets are finer, more oblique, and more distant than in *N. heterophylla*. The pinnules of *N. ovata* forma *flexuosa* are broader in proportion to their length and taper less toward the apex; the lateral veinlets are more divided and slightly more numerous than in *N. tenuifolia*. The lateral veinlets of the pin-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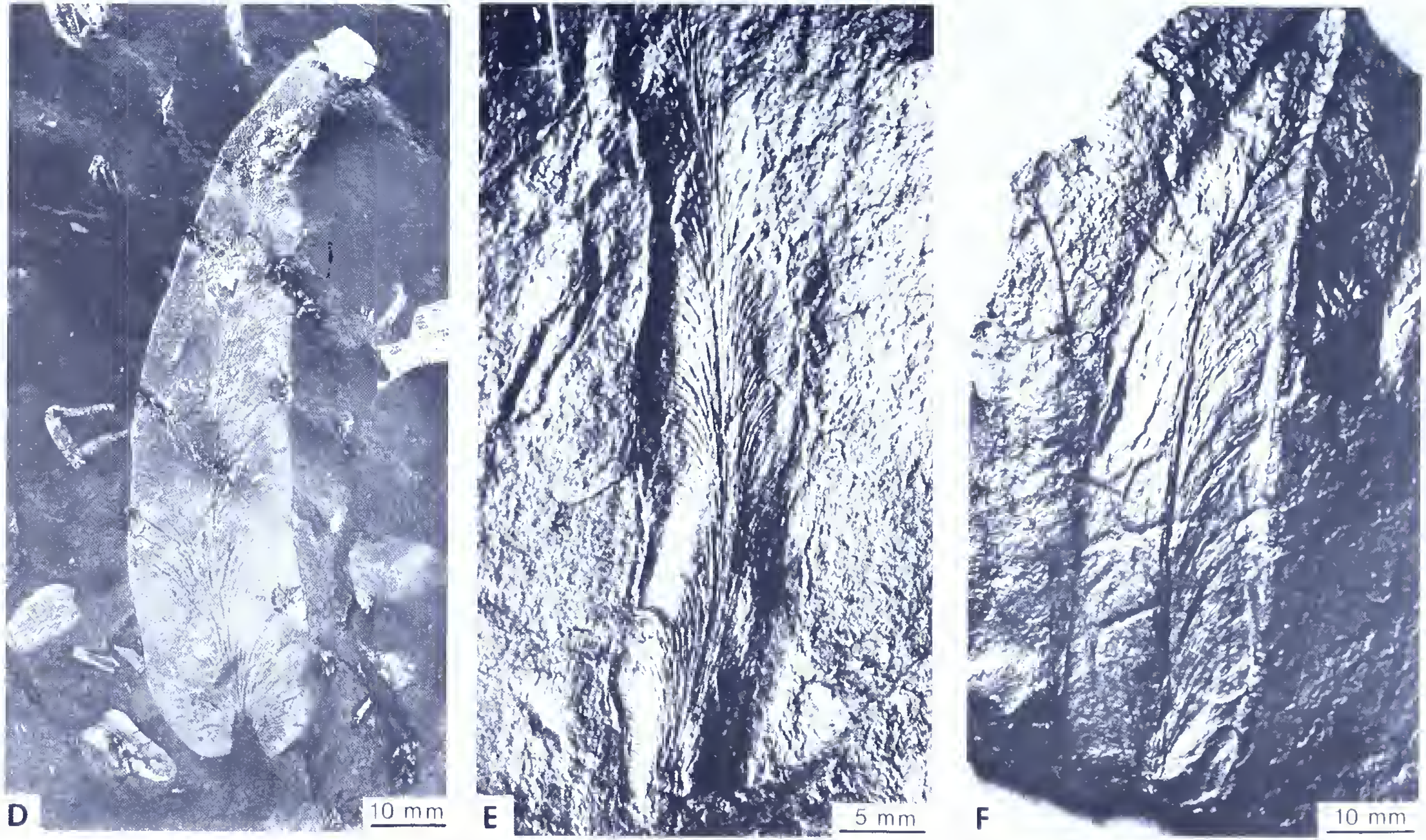


Figure 24. A. *Neuropteris decipiens* Lesquereux [WPMM F689]; B, C, D, E, F. *Neuropteris scheuchzeri* Hoffmann (different shape of pinnules of this species) [WPMM F719, F720, F722, F728a, F728b].

nules of *N. rarinervis* are strong, distant, more arched, and divided at a wider angle than in *N. tenuifolia.*

DISTRIBUTION: *Neuropteris tenuifolia* occurs mainly in the upper Pottsvillian (Westphalian B) and is rare in the Alleghenian (Westphalian C and lower D) of the central and Appalachian regions in the United States. It also occurs in the Minto Formation (Pictou Group) of New Brunswick and in the Morien (Pictou) Group (Westphalian C and D) of Nova Scotia, Canada. In Europe, this species is widespread and ranges from Namurian B to Westphalian D, but it is most common in the Westphalian A, B, and C.

SPECIMEN: WPMM F597.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus *Linopteris* Presl, 1838

Linopteris neuropteroides (Gutbier) Potonié, 1899

(Figure 25G)

Dictyopteris brongniarti Gutbier, 1835, p. 63, pl. 11, figs. 7-10.
Linopteris gutbieriana Presl, 1838, in Sternberg, 1838, p. 167.
Linopteris neuropteroides Gutbier. Potonié, 1899, p. 153.
Linopteris neuropteroides var. *major* Potonié. Bell, 1938, p. 66, pl. 61, figs. 1-4.
Linopteris neuropteroides Geinitz. Crookall, 1959, p. 209, pl. 48, fig. 4; text-figs. 71, 72. (Contains a more complete synonymy.)

DESCRIPTION: Specimens of this species represent only detached, elongate, more or less falcate pinnules that range from 16 to 20 mm in length and 6 to 9 mm in width and have slightly cordate bases. Margins in the lower portion of the pinnules are nearly parallel; in the upper portion they taper gradually to an obtuse apex. The median vein is fairly strong near the base and visible up to four fifths the length of the pinnule. Secondary veinlets are distinct and closely spaced; they ascend strongly near the midvein, then arch toward the margin, anastomosing to form a delicate network of elongate, sharply pointed meshes, which number about seven from the midvein to the margin, and meet obliquely.

REMARKS: *Linopteris neuropteroides* is closely allied to *L. obliqua* Bunbury. The venations of both have a perfect arrangement and both are homeomorphs of *Neuropteris gigantea* Sternberg. The main differences between these two species are in the shape, size, and venation of the pinnules. The pinnules of *L. neuropteroides* are more elongate, and the upper portions of the pinnule margins gradually taper, usually to an obtuse apex; the network of veinlet meshes is closely spaced and sharply pointed. *Linopteris* *obliqua* has elongate-ovate pinnules with broadly rounded apices, and the veinlet meshes are polygonal, less elongate, narrower, and less sharply pointed.

DISTRIBUTION: *Linopteris neuropteroides* is known from Alleghenian and equivalent strata (Westphalian C and lower D) in the central and Appalachian regions of the United States. It is also found in the Morien (Pictou) Group (Westphalian C and D) of the Sydney coal field in Nova Scotia, Canada. In Europe, this species occurs in the Westphalian C and D.

SPECIMEN: WPMM F718.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

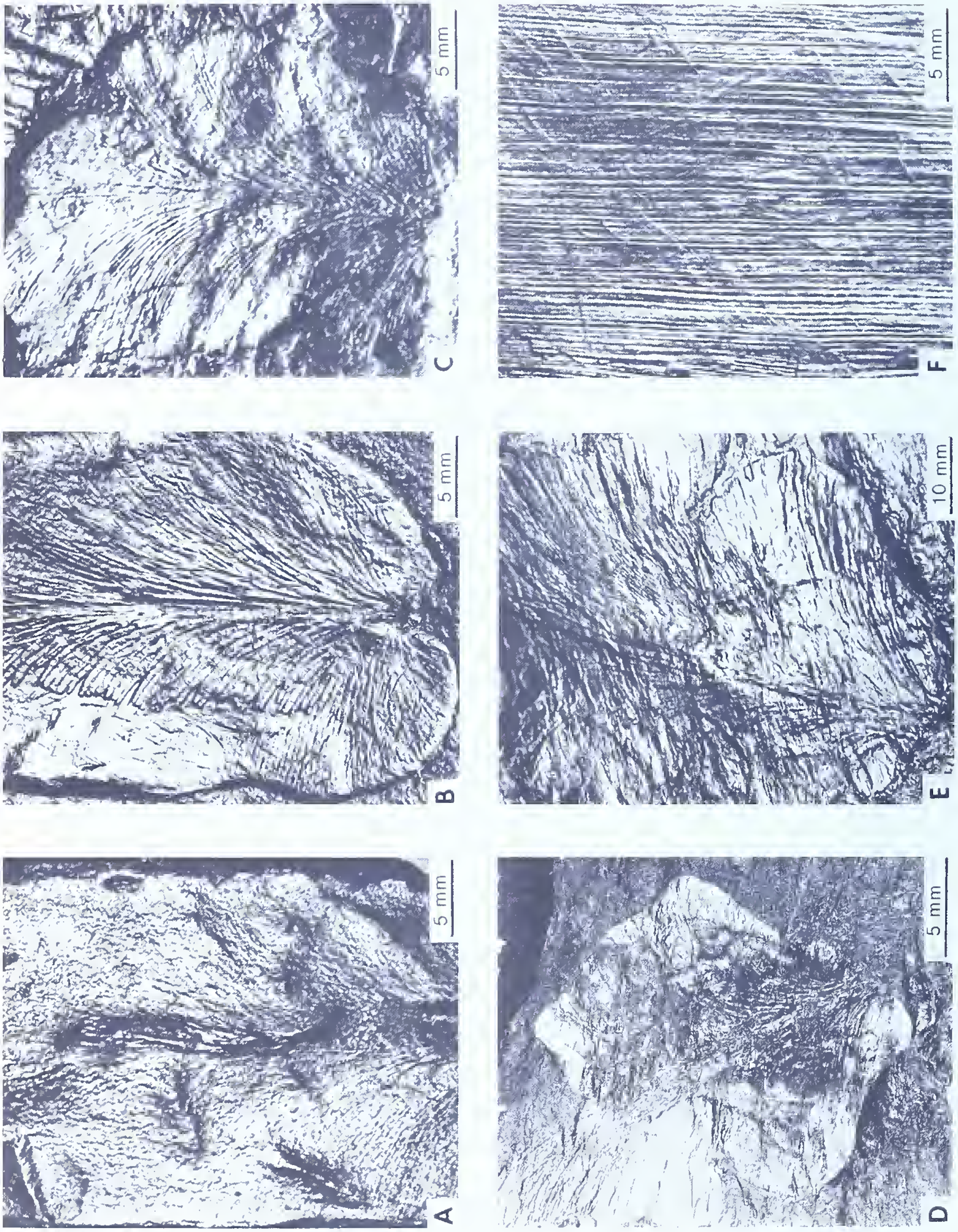
Linopteris obliqua (Bunbury) Zeiller, 1899
(Figure 25H)

Dictyopteris obliqua Bunbury, 1847, p. 427, pl. 21, fig. 2A, B.
Dictyopteris obliqua Bunbury. Lesquereux, 1879, pl. 23, figs. 4-6; 1880, p. 146.
Linopteris obliqua (Bunbury). Zeiller, 1899, p. 46, pl. 4, figs. 4-6.
Linopteris obliqua (Bunbury). Bell, 1938, p. 64, pl. 58, figs. 4, 5.
Linopteris obliqua Bunbury. Crookall, 1959, p. 205, pl. 48, fig. 6; text-figs. 69, 70, 72A. (Contains a more complete synonymy.)

DESCRIPTION: The specimens represent many detached falcate pinnules that have nearly straight bases and margins which gradually taper to a rounded apex. The median vein is flexuous and traceable for about three fifths the length of a pinnule. Lateral veinlets are distinct and form a close mesh of four- to six-sided polygons; those near the midvein are elongated and strongly ascending, whereas those farther from the midvein are progressively shorter and inclined towards the margin of the pinnule, meeting it obliquely. About eight meshes occur between the midvein and the margin of the pinnule.

REMARKS: The main differences between *Linopteris obliqua* and *L. neuropteroides* (Gutbier) Potonié are in the shape of the pinnules and their venation. The pinnules of the former species are more falcate and the network of veinlets less elongate than in *L. neuropteroides*.

DISTRIBUTION: *Linopteris obliqua* is known from uppermost Pottsvillian and Alleghenian (Westphalian B_2, C, and lower D) strata and their equivalents in the central and Appalachian regions of the United States. It is known also from the *Linopteris obliqua* Zone in the Morien (Pictou) Group (Westphalian C) of the Sydney coal field in Nova Scotia, Canada. In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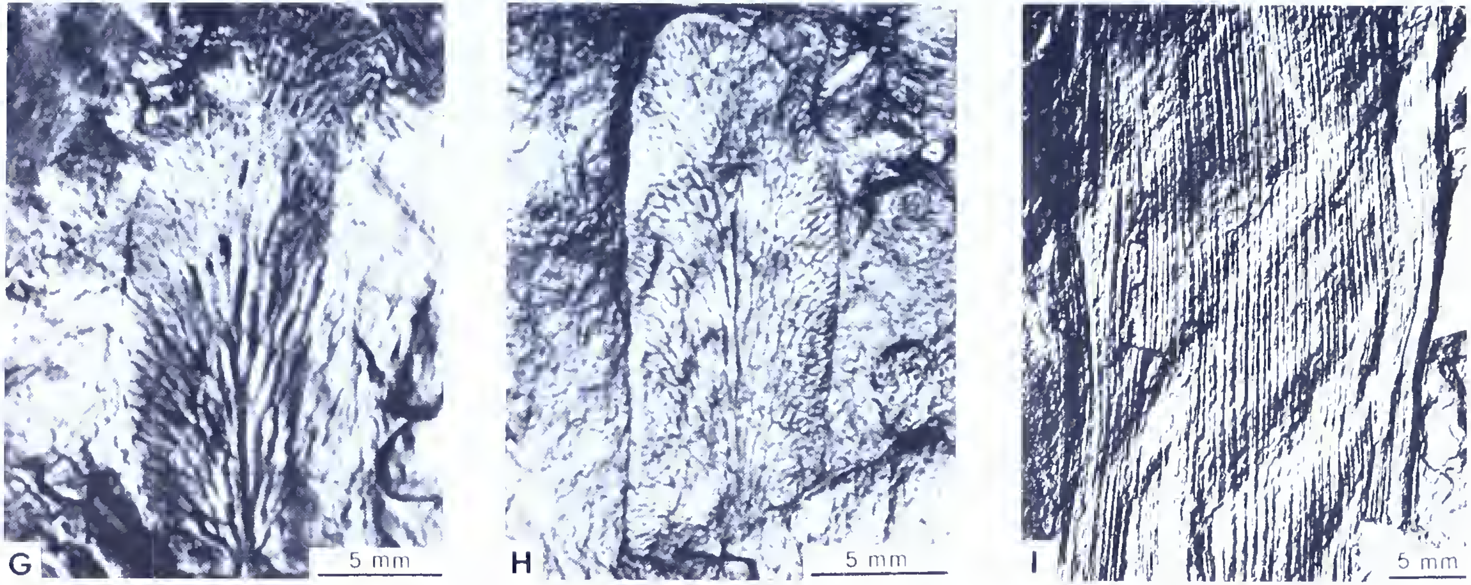


Figure 25. A, B. *Neuropteris scheuchzeri* Hoffmann (with stiff hairs on the lower surface of pinnules) [WPMM F580, F655]; C, D. *Neuropteris ovata* Hoffmann forma *typica* (cyclopteroid pinnules) [WPMM F708]; F. *Cordaites principalis* (Germar) Geinitz [WPMM F695]; G. *Linopteris neuropteroides* (Gutbier) *Potonié* [WPMM F718]; H. *Linopteris obliqua* (Bunbury) Zeiller [WPMM F718c]; I. *Cordaites* cf. *borassifolia(us)* (Sternberg) Unger [WPMM F606].

Europe, this species is known from the Westphalian B and C, and more rarely from the Westphalian D.

SPECIMEN: WPMM F718c.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus *Odontopteris* Brongniart, 1825

Odontopteris subcuneata Bunbury, 1847

(Figure 26A)

Odontopteris subcuneata Bunbury, 1847, p. 427, pl. 23, fig. 1A, B.

Odontopteris subcuneata Bunbury. Lesquereux, 1879, pl. 22, figs. 4, 5; 1880, p. 134.

Odontopteris subcuneata Bunbury. Bell, 1938, p. 62, pl. 57, figs. 1-8; pl. 58, figs. 1-3.

Odontopteris subcuneata Bunbury. Darrah, 1970, p. 148, pl. 62, fig. 4.

DESCRIPTION: This polymorphic pteridophyll is represented by many fragments of terminal portions of pinnae. The pinnules are alternate, oblique, usually conspicuously decurrent, basally contracted, slightly auricled, and obovate; there is one tapering acuminate pinnule. The veins enter the pinnule directly from the rachis; in some specimens a principal vein ascends parallel to the rachis, and, further up the pinnule, divides and extends toward the margin. Small dark spots on the surface of the pinnules are probably traces of hairs.

REMARKS: The most important characteristics of the odontopterids are the broad, decurrent attachment of the pinnules to the rachis, and the veins that enter the pinnules along the whole base of the attachment to the rachis, and which then curve toward the margins of the pinnules. Obscure traces of hairs on the pinnules, similar to those present in *Neuropteris scheuchzeri* Hoffmann, suggested to White (1899) that the odontopterids, to which *O. subcuneata* and *O. wortheni* Lesquereux belong, is made up of anomalous or heteromorphous pinnae and pinnules of the genus *Neuropteris*.

DISTRIBUTION: *Odontopteris subcuneata* in North America is reported from the same strata in which the long-pinnuled species of neuropteroids, such as *Neuropteris scheuchzeri* Hoffmann, *N. decipiens* Lesquereux, and *N. hirsuta* Lesquereux, are common. This species is known from the central and Appalachian regions of the United States, and from the Morien (Pictou) Group of the Sydney coal field in Nova Scotia, Canada. In Europe, this species is known from uppermost Westphalian D, Stephanian, and Rothliegend (Lower Permian) strata.

SPECIMENS: WPMM F600, F601.

LOCALITY: St. Clair, near Pottsville, Pennsylvania, Southern Anthracite coal basin, Llewellyn Formation, Buck Mountain (No. 5) coal bed.

Order CORDAITALES

Family CORDAITACEAE

Genus *Cordaites* Unger, 1850

Cordaites cf. *borassifolia(us)* (Sternberg) Unger, 1850

(Figure 251)

Flabellaria borassifolia Sternberg, 1823, p. 27, 32, pl. 18.

Cordaites borassifolia(us) (Sternberg). Unger, 1850, p. 277.

Cordaites borassifolius (Sternberg) Unger. Lesquereux, 1879, pl. 76, figs. 3, 3b; 1880, p. 532.

Cordaites borassifolius Sternberg. Crookall, 1970, p. 807, pl. 153, fig. 3; text-fig. 231. (Contains a more complete synonymy.)

DESCRIPTION: The specimens show fragments of leaves, some of which are 63 mm wide, and some deeply lacerated. The veins are straight, parallel to the margins of the leaves and to each other, and alternately thick and thin; there are about 23 thick veins per centimeter. In some places, short, transverse, oblique lines occur on the surface of the leaf between the veins.

REMARKS: *Cordaites borassifolius* differs from *C. principalis* Germar and *C. communis* Lesquereux by its different venation. The venation of *C. borassifolius* is represented by a close alternation of thick and thin parallel veins, whereas *C. principalis* has two to five thin, secondary veins between each pair of thick veins, which are usually not equally spaced; there are often transverse oblique lines, due to parenchyma, between the thin, secondary veins. The venation of *C. communis* is very irregular in character and in apparent density; in some parts of the same leaf it consists of strong veins close together or separated by one to three or four thinner veins, whereas in other parts of the leaf, strong veins are more distant, separated by four to six fine veins.

DISTRIBUTION: *Cordaites borassifolius* is known from upper Pottsvillian to lower Monongahelan (Westphalian B_2 to Stephanian lower B) strata in the central and Appalachian regions of the United States. In Europe, this species ranges from the Westphalian D to Rothliegend (Lower Permian).

SPECIMEN: WPMM F606.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Cordaites principalis (Germar) Geinitz, 1855
(Figure 25F)

Flabellaria principalis Germar, 1848, p. 55, pl. 23.
Cordaites principalis (Germar). Geinitz, 1855, p. 41, pl. 21, figs. 1, 2, 2a, 2b.
Cordaites principalis (Germar). Bell, 1938, p. 103, pl. 105, fig. 1; pl. 106, fig. 1.
Cordaites principalis Germar. Oleksyshyn, 1976, p. 171, 173; text-fig. 15A.

DESCRIPTION: The specimens represent a few fragments of leaves, 4 to 6 cm broad, that have parallel venation consisting of coarse longitudinal primary veins between which are two to six, but most commonly two or three, thin, longitudinal secondary veins.

REMARKS: *Cordaites principalis* very often is confused with *C. borassifolia(us)* (Sternberg) Unger. The main difference between these two species is in the shape of the leaves and their venation. In typical examples the leaves of *C. principalis* are narrow-lanceolate, whereas in *C. borassifolia(us)* they are ovate-lanceolate, and the apices of the leaves in *C. principalis* are more rounded than in *C. borassifolia(us)*. The venation of the latter consists of distinct, alternately thick and fine longitudinal veins. The veins of *C. principalis* are closer together than those of *C. borassifolia(us)*.

DISTRIBUTION: In the United States, *Cordaites principalis* is known from Alleghenian, Conemaughian, and Monongahelan (Westphalian D to Stephanian C) strata in the central and Appalachian regions, and from the Narragansett basin. It is also known from the Lancaster Formation of the Cumberland Group (Westphalian B) and the Minto Formation (Pictou Group) (Westphalian C and D) of New Brunswick, Canada, and from the Morien (Pictou) Group of the Sydney coal field in Nova Scotia, Canada. In Europe, this species ranges from Namurian B to Lower Permian.

SPECIMEN: WPMM F695.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Genus *Cordaitanthus* O. Feistmantel, 1876
Cordaitanthus spinosus (Dawson) Bell, 1938
(Figure 26B)

Antholites spinosus Dawson, 1868, p. 459, 460, fig. 173C.
Cordaitanthus spinosus (Dawson). Bell, 1938, p. 105, pl. 105, figs. 2, 3.

DESCRIPTION: The figured specimen is a stout, ovate, longitudinally striated shoot, 65 mm long and 2 mm broad at the base, gradually decreasing in width to the apex and bearing alternate, double rows of upward-curving bracts. Sterile, linear bracts, arising from the shoot almost at right angles and about 2 mm from the axis, ascend obliquely, and some reach a length of 22 mm. Such longitudinally furrowed bracts are somewhat angular in cross section and are close together in the upper portion of the shoot but more distant in the lower portion. The oval compact buds, made of female-lanceolate scales, are situated in the axil of each sterile bract. Individual scales, 3.5 to 7.5 mm long and 2 to 3 mm broad, have concave upper surfaces and are delicately striated. The bases of the lowermost bracts partially overlap the axes of the shoots. Inside of such ovate-lanceolate bracts is a pedicel about 6 mm long, which bears a single small oval seed, 3 to 6 mm long and 2.5 to 4 mm broad. The seed has an emarginate apex (i.e., the upper margin is notched), and the surface of the seed is commonly marked by radial wrinkles.

REMARKS: In *Cordaitanthus spinosus*, the cordaitean cone-bearing parts, or strobili, are known to be either male (polleniferous) or female (ovulate). This species is closely allied to *C. volkmanni* Ettingshausen and differs mainly in the somewhat larger sterile bracts, which reach a length of 2 cm or more. The name of this "genus" is transferred from *Cordaianthus* Grand' Eury (1877, p. 227) to *Cordaitanthus* O. Feistmantel (1876, p. 272), because the latter has priority over the widely used name *Cordaianthus*.

DISTRIBUTION: *Cordaitanthus spinosus* ranges in North America from uppermost Pottsvillian to upper Alleghenian (Westphalian B_2, C, and lower D). This species is known from the central and Appalachian regions of the United States and from the *Linopteris obliqua* Zone of the Morien (Pictou) Group of the Sydney coal field of Nova Scotia, Canada.

SPECIMEN: WPMM F699.

LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

Cordaitanthus volkmannii Ettingshausen, 1851
(Figure 26C)

Calamites volkmanni Ettingshausen, 1851, pl. 5, figs. 1-3.
Cordaianthus volkmanni Ettingshausen. Zeiller, 1886, p. 637, pl. 94, fig. 6.
Cordaitanthus volkmanni Ettingshausen, pars. comb. nov., Crookall, 1970, p. 428, pl. 158, fig. 4; text-fig. 239. (Contains a more complete synonymy.)

DESCRIPTION: The figured specimen is an axis of a longitudinally costate, ovulate shoot up to 9 cm long and 1.7 mm broad at the base (though some separate fragments of shoots may be up to 2.8 mm broad); the breadth decreases gradually toward the apex. The axis bears alternate,

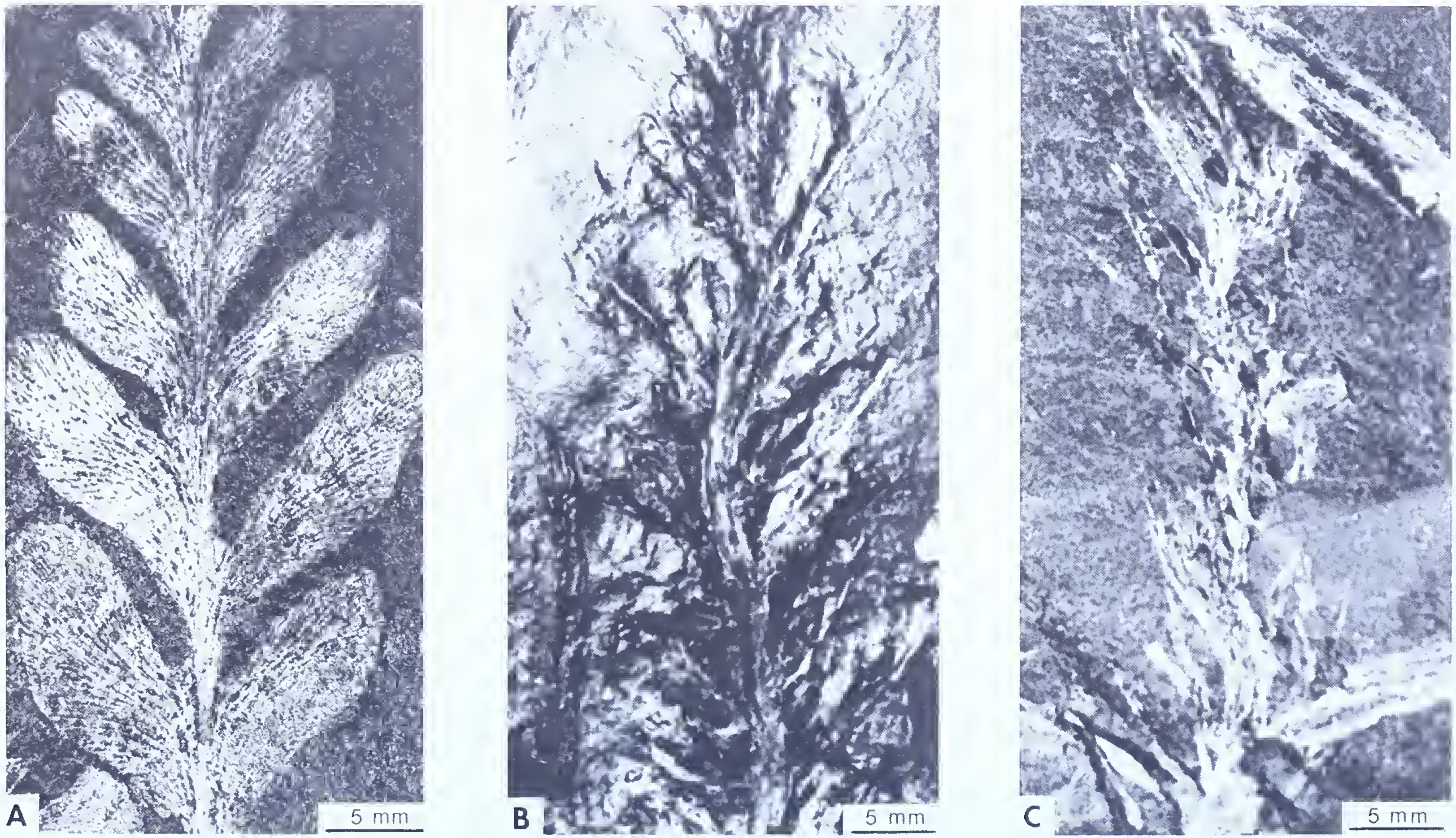


Figure 26. A. *Odontopteris subcuneata* Bunbury [WPMM F600]; B. *Cordaitanthus spinosus* (Dawson) Bell [WPMM F699]; C. *Cordaitanthus volkmannii* Ettingshausen [WPMM F608].

double rows of upward-curving bracts from the axils of which arise the buds or dwarf-shoots. The bracts are setaceous, linear-lanceolate, and relatively long, up to about 15 mm; they generally curve toward the axis and are about 1 mm broad in the upper part of the shoot. The dwarf-shoots are ovoid, up to 5 mm long and 2 to 3 mm broad, and composed of imbricated scales.

REMARKS: *Cordaitanthus volkmannii* is closely allied to *C. spinosus* (Dawson) Bell, but in the former the sterile bracts are longer, reaching a length of about 2 cm or more.

DISTRIBUTION: *Cordaitanthus volkmannii* is known only from Alleghenian (Westphalian C and lower D) strata in the Appalachian region. In Europe, this species is rare in the Westphalian A, B, and lower C.

SPECIMEN: WPMM F608.

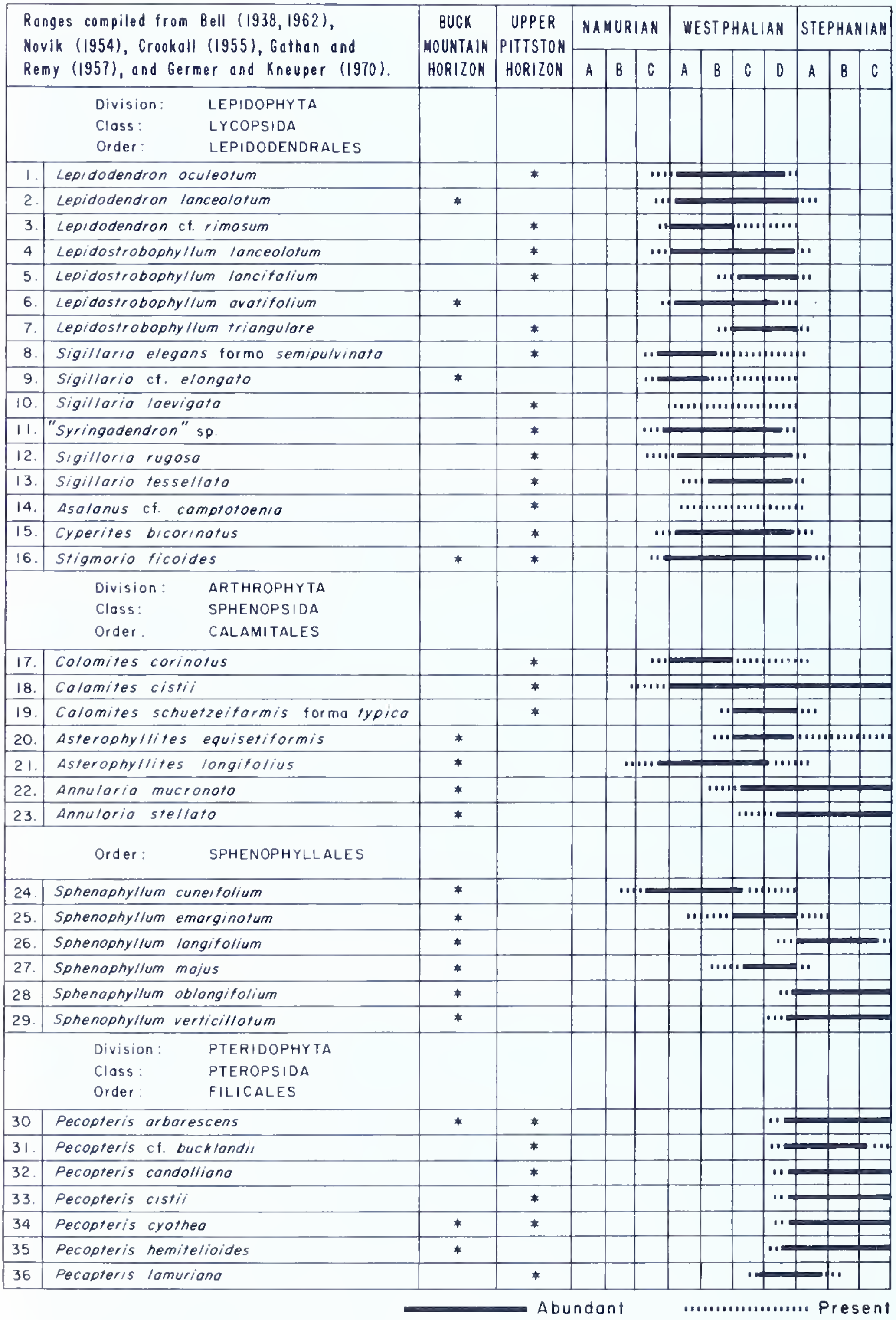
LOCALITY: Wanamie, near Wilkes-Barre, Pennsylvania, Northern Anthracite coal basin, Llewellyn Formation, Baltimore coal bed.

COMPARISON OF FOSSIL PLANTS FROM CONTEMPORANEOUS STRATA IN THE OTHER COAL BASINS IN NORTH AMERICA AND EUROPE

The most characteristic fossil plants growing at the same time in some other Upper Carboniferous coal basins of North America and Europe can be summarized briefly.

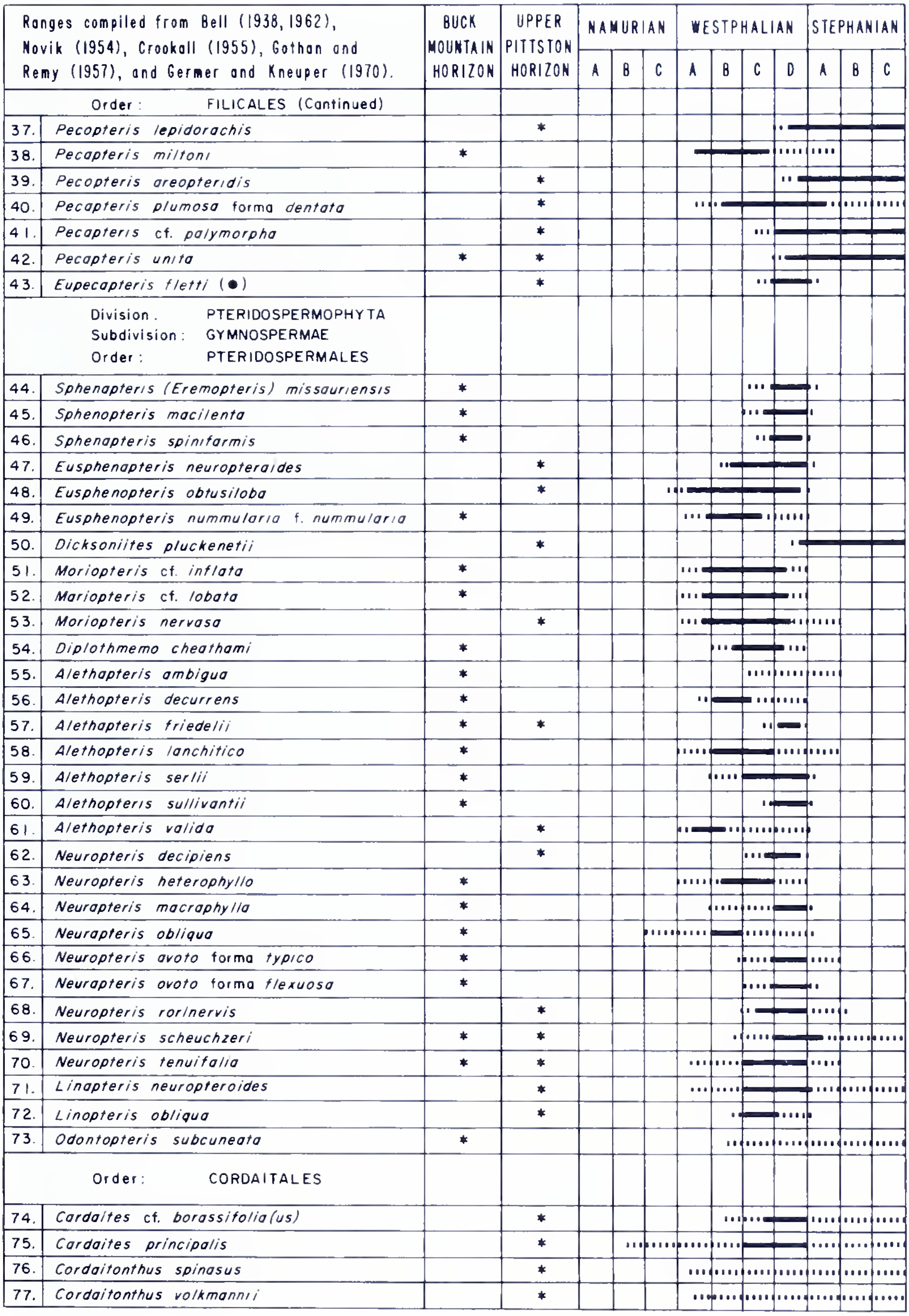
The Buck Mountain (No. 5) coal bed in the lower portion of the Llewellyn Formation in the Southern Anthracite coal basin of eastern Pennsylvania, on the basis of the megaflora, may be correlated with the Upper Kittanning coal bed in the middle of the Allegheny Formation or Group in southwestern Pennsylvania, eastern Ohio, and northern West Virginia, and with the lower horizon of the upper part of the Des Moines Series in the Midcontinent region. The most characteristic fossil plants in this horizon are *Neuropteris ovata*, *N. scheuchzeri*, *Alethopteris serlii*, *Pecopteris lamuriana*, *P. unita*, *Asterophyllites equisetiformis*, *Sphenophyllum emarginatum*, and some others, which indicates that the geologic age of these strata is Westphalian D (Figure 27).

The Baltimore (Pittston) coal bed, in a slightly higher position in the Llewellyn Formation in the Northern Anthracite coal basin of eastern Pennsylvania, may be correlated with the Upper Freeport coal bed, the highest coal in the Allegheny Formation or Group in the central and Appalachian regions. The most characteristic fossil plants in this horizon are *Neuropteris ovata*, *N. scheuchzeri*, *Linopteris obliqua*, *Alethopteris serlii*, *Pecopteris*



	Ranges compiled from Bell (1938, 1962), Novik (1954), Crookall (1955), Gothan and Remy (1957), and Germer and Kneuper (1970).	BUCK MOUNTAIN HORIZON	UPPER PITTSTON HORIZON
	Division: LEPIDOPHYTA Class: LYCOPSIDA Order: LEPIDODENDRALES		
1.	*Lepidodendron aculeatum*		*
2.	*Lepidodendron lanceolatum*	*	
3.	*Lepidodendron* cf. *rimosum*		*
4	*Lepidostrobophyllum lanceolatum*		*
5.	*Lepidostrobophyllum lancifolium*		*
6.	*Lepidostrobophyllum ovatifolium*	*	
7.	*Lepidostrobophyllum triangulare*		*
8.	*Sigillaria elegans* forma *semipulvinata*		*
9.	*Sigillaria* cf. *elongata*	*	
10.	*Sigillaria laevigata*		*
11.	"*Syringodendron*" sp.		*
12.	*Sigillaria rugosa*		*
13.	*Sigillaria tessellata*		*
14.	*Asolanus* cf. *camptotaenia*		*
15.	*Cyperites bicarinatus*		*
16.	*Stigmaria ficoides*	*	*
	Division: ARTHROPHYTA Class: SPHENOPSIDA Order: CALAMITALES		
17.	*Calamites carinatus*		*
18.	*Calamites cistii*		*
19.	*Calamites schuetzeiformis* forma *typica*		*
20.	*Asterophyllites equisetiformis*	*	
21.	*Asterophyllites longifolius*	*	
22.	*Annularia mucronata*	*	
23.	*Annularia stellata*	*	
	Order: SPHENOPHYLLALES		
24.	*Sphenophyllum cuneifolium*	*	
25.	*Sphenophyllum emarginatum*	*	
26.	*Sphenophyllum longifolium*	*	
27.	*Sphenophyllum majus*	*	
28	*Sphenophyllum oblongifolium*	*	
29.	*Sphenophyllum verticillatum*	*	
	Division: PTERIDOPHYTA Class: PTEROPSIDA Order: FILICALES		
30	*Pecopteris arborescens*	*	*
31.	*Pecopteris* cf. *bucklandii*		*
32.	*Pecopteris candolliana*		*
33.	*Pecopteris cistii*		*
34	*Pecopteris cyathea*	*	*
35	*Pecopteris hemitelioides*	*	
36	*Pecopteris lamuriana*		*

Figure 27. Charts showing the geologic ranges of fossil plants found in the Buck Mountain (No. 5) horizon of the Southern Anthracite coal basin and in the Baltimore (Upper Pittston) horizon of the Northern Anthracite coal basin, eastern Pennsylvania.



	Ranges compiled from Bell (1938, 1962), Novik (1954), Crookall (1955), Gothan and Remy (1957), and Germer and Kneuper (1970).	BUCK MOUNTAIN HORIZON	UPPER PITTSTON HORIZON
	Order: FILICALES (Continued)		
37.	*Pecopteris lepidorachis*		*
38.	*Pecopteris miltoni*	*	
39.	*Pecopteris oreopteridis*		*
40.	*Pecopteris plumosa* forma *dentata*		*
41.	*Pecopteris* cf. *polymorpha*		*
42.	*Pecopteris unita*	*	*
43.	*Eupecopteris fletti* (●)		*
	Division: PTERIDOSPERMOPHYTA Subdivision: GYMNOSPERMAE Order: PTERIDOSPERMALES		
44.	*Sphenopteris (Eremopteris) missouriensis*	*	
45.	*Sphenopteris macilenta*	*	
46.	*Sphenopteris spiniformis*	*	
47.	*Eusphenopteris neuropteroides*		*
48.	*Eusphenopteris obtusiloba*		*
49.	*Eusphenopteris nummularia* f. *nummularia*	*	
50.	*Dicksoniites pluckenetii*		*
51.	*Mariopteris* cf. *inflata*	*	
52.	*Mariopteris* cf. *lobata*	*	
53.	*Mariopteris nervosa*		*
54.	*Diplothmema cheathami*	*	
55.	*Alethopteris ambigua*	*	
56.	*Alethopteris decurrens*	*	
57.	*Alethopteris friedelii*	*	*
58.	*Alethopteris lonchitica*	*	
59.	*Alethopteris serlii*	*	
60.	*Alethopteris sullivantii*	*	
61.	*Alethopteris valida*		*
62.	*Neuropteris decipiens*		*
63.	*Neuropteris heterophylla*	*	
64.	*Neuropteris macrophylla*	*	
65.	*Neuropteris obliqua*	*	
66.	*Neuropteris ovata* forma *typica*	*	
67.	*Neuropteris ovata* forma *flexuosa*	*	
68.	*Neuropteris rarinervis*		*
69.	*Neuropteris scheuchzeri*	*	*
70.	*Neuropteris tenuifolia*	*	*
71.	*Linopteris neuropteroides*		*
72.	*Linopteris obliqua*		*
73.	*Odontopteris subcuneata*	*	
	Order: CORDAITALES		
74.	*Cordaites* cf. *borassifolia(us)*		*
75.	*Cordaites principalis*		*
76.	*Cordaitanthus spinosus*		*
77.	*Cordaitanthus volkmanni*		*

(●) First time recorded from U.S.A.

Figure 27. (*Continued*).

arborescens, *P. plumosa* forma *dentata*, *P. hemitelioides*, *P. lamuriana*, *P. oreopteridis*, *P. unita*, *Calamites cistii*, and some others, which indicates that the geologic age of these strata is also Westphalian D (Figure 27) (Darrah, 1970, p. 9, 10).

MARITIME PROVINCES OF EASTERN CANADA

Characteristic fossil plants in the upper portion of the Pictou Group, found in the *Ptychocarpus unitus* Zone (above) and in the upper portion of the *Linopteris obliqua* Zone (below) are *Pecopteris polymorpha*, *P. unita*, *Dicksoniites pluckenetii*, *Neuropteris ovata*, *N. scheuchzeri*, *N. macrophylla*, *Linopteris obliqua*, *Mariopteris nervosa*, *Alethopteris friedelii*, *A. serlii*, *A. valida*, *Lepidodendron wortheni*, *Sigillaria tessellata*, *Asterophyllites equisetiformis*, and some others, which indicates that the geologic age of these strata is Westphalian D (Bell, 1938, charts 1, 2, 3; 1944).

SOUTH WALES COAL FIELD OF GREAT BRITAIN

The most characteristic fossil plants of the strata of the Radstockian Stage in the South Wales coal field are *Pecopteris arborescens*, *P. candolliana*, *P. crenulata*, *P. cyathea*, *P. daubrei*, *P. hemitelioides*, *P. lamuriana*, *P. lepidorachis*, *P. oreopteridis*, *P. polymorpha*, *P. unita*, *P. bucklandii*, *P. cistii*, *P. pteroides*, *P. villosa*, *Eupecopteris fletti*, *Dicksoniites pluckenetii*, *Neuropteris ovata*, *N. flexuosa*, *N. macrophylla*, *Sphenopteris macilenta*, *S. neuropteroides*, and some others, which indicates that the strata of the Radstockian Stage in this coal field are of Westphalian D age (Crookall, 1955, p. 2-5, chart A; Chaloner and Collinson, 1975, p. 39-41).

SAAR COAL BASIN OF WESTERN GERMANY

Late Carboniferous strata of the Upper Saarbruecker Group (Westphalian D) in the Saar Basin consist of three horizons: (1) the Geischeck beds (oldest); (2) the Luisenthaler beds (middle); and (3) the Heiligenwalder beds (youngest).

At the beginning of the deposition of Geischeck beds many plants characteristic of Westphalian C were already extinct, and the new forms appeared (Germer and Kneuper, 1970; Germer, 1971). The most characteristic plants of the Geischeck beds are *Neuropteris obliqua, Sphenopteris damesi, Eupecopteris geischecki, Dicksoniites geischecki, Sphenophyllum geischecki, Mariopteris nervosa, Asterophyllites longifolius*, and *Palaeoweichselia defrancei*. Impressions of *Pecopteris unita, P. hemitelioides*, and *P. oreopteridis* were only rarely found in these beds.

At the beginning of the deposition of Luisenthaler beds, *Neuropteris ovata* appeared for the first time in this basin. *Mariopteris nervosa, M. latifolia, Margaritopteris coemansi, Palaeoweichselia defrancei, Annularia* *sphenophylloides, A. stellata,* and *N. ovata* are the characteristic fossil plants for the Luisenthaler strata.

During the deposition of the Heiligenwalder beds many new forms appeared, which later, during Stephanian time, became the dominant plants. To such plants belong *Dicksoniites pluckenetii, Pecopteris arborescens, P. lamuriana,* and *Danaeites saraepontanus.* These species, together with *Neuropteris ovata, Linopteris obliqua, L. neuropteroides,* and *Annularia stellata,* are characteristic fossil plants for Heiligenwalder strata. On the basis of fossil remains, the Heiligenwalder beds may be correlated with the Buck Mountain and Baltimore horizons in the Anthracite coal region of eastern Pennsylvania.

The earth-crustal movements of the Asturian phase at the end of Westphalian D time caused an interruption in sedimentation and major changes in the climate and vegetation in the type region of the Westphalian Stage in the Saar-Lorraine basin. *Neuropteris ovata, Mariopteris nervosa,* and many other Westphalian plants became extinct, and more new, Stephanian, forms appeared (Guthorl, 1952; Gothan and Remy, 1957; Germer and Kneuper, 1970).

UPPER SILESIAN COAL BASIN OF POLAND

As in the other Carboniferous coal basins, a notable change in the flora took place in the Upper Silesian coal basin at the end of Westphalian C time, when a large number of species became extinct and new forms appeared during Westphalian D. Westphalian D, to which the Libiaz beds belong, was a particularly important time in the development of the Upper Carboniferous flora; it was characterized by a large proportion of ferns and lycopods, which formed a connecting link between the flora of Westphalian D and the flora of the Stephanian Stage. The most characteristic fossil plants of the Libiaz beds in the Upper Silesian basin are *Neuropteris ovata, N. scheuchzeri, Pecopteris abbreviata, P. arborescens, P. armasi, P. cyathea, P. lamuriana, P. pseudovestita, P. unita, Dicksoniites pluckenetii, Annularia sphenophylloides, Sphenophyllum emarginatum,* and some others (Stopa, 1957; Migier, 1972).

OSTRAVA-CARVINA COAL DISTRICT OF CZECHOSLOVAKIA

The characteristic fossil plants found in the Upper Carboniferous strata of Westphalian D age in the Ostrava-Carvina coal district are *Neuropteris ovata, Linopteris neuropteroides, L. obliqua, Mariopteris nervosa, Eusphenopteris nummularia, Pecopteris ambigua, P. unita, Dicksoniites pluckenetii, Sigillaria tessellata, Annularia stellata, A. sphenophylloides, Sphenophyllum emarginatum, S. majus, S. verticillatum,* and some others (Havlena, 1960, p. 286).

CARBONIFEROUS DONETZ BASIN OF UKRAINE

A major change in vegetation also took place in the Donetz basin at the end of Westphalian C time and during Westphalian D. At this time, many of the plants became extinct and new forms appeared, which later, during Stephanian time, reached their climax of development. The most characteristic fossil plants found in the Upper Carboniferous strata of Westphalian D age in this basin are *Neuropteris ovata, N. scheuchzeri, Linopteris neuropteroides, Mariopteris plumosa, Pecopteris candolliana, P. cyathea, P. daubrei, P. oreopteridis, P. unita, Eupecopteris bucklandii, Annularia stellata, Sphenophyllum verticillatum, Cordaites borassifolius, Calamostachya tuberculata*, and some others, known also from Upper Carboniferous strata of Westphalian D age in the above-mentioned coal basins in North America and Europe (Novik, 1954, charts I and II).

CONCLUSIONS

A series of orogenic phases of the Alleghanian-Hercynian orogeny caused changes in the climatic conditions and in the vegetation of those regions on the Laurasian landmass that were affected by these earth-crustal movements during Late Paleozoic time.

One such change took place at the end of Westphalian C time, when many species, especially of the families Neuropteridaceae and Alethopteridaceae, the predominant plants during Westphalian B and C times, became extinct. New forms, especially ferns (Filicales) and plants of some other orders, appeared for the first time during the Westphalian D, many of which later reached their climax during Stephanian time.

At the Buck Mountain horizon, in the lower portion of the Llewellyn Formation in the Southern Anthracite coal basin of eastern Pennsylvania, the following new forms occurred: *Pecopteris arborescens, P. cyathea, P. hemitelioides, P. unita, Neuropteris ovata* forma *flexuosa, Alethopteris friedelii, A. sullivantii, Sphenophyllum longifolium, S. oblongifolium*, and some others, which indicates that the geologic age of strata in the Buck Mountain (No. 5) horizon is Westphalian D.

In the Baltimore (Pittston) horizon, also in the lower portion of the Llewellyn Formation in the Northern Anthracite coal basin of eastern Pennsylvania, at a slightly higher position than the Buck Mountain (No. 5) horizon, the following new forms occurred: *Pecopteris arborescens, P. bucklandii, P. candolliana, P. cistii, P. cyathea, P. lamuriana, P. lepidorachis, P. oreopteridis, P. polymorpha, P. unita, Eupecopteris fletti, E. pluckenetii, Alethopteris friedelii*, and some others, which indicates that the geologic age of strata in the Baltimore (Pittston) horizon is also Westphalian D.

Abundant *Neuropteris ovata* forma *flexuosa* and the appearance of many different cyatheoid species of *Pecopteris* in both horizons indicate that the fossil plants described in this paper correspond to the 10th floral zone of Read and Mamay (1964, p. K10).

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GLOSSARY[1]

Abaxial surface. The surface of a leaf directed away from the stem on which it rises; the underside of a leaf.

Acuminate. Pointed.

Acute. Pertaining to an angle of less than 90 degrees; also said of a leaf that ends in a sharp point.

Adaxial surface. The surface of a leaf facing the stem on which it rises; the upper side of a leaf.

Alate. Having wings or a winglike part.

Alethopteroid. Referring to pinnules that are attached to the rachis by decurrent, and often confluent, bases.

Alternate. Referring to a bud or leaf arrangement in which there is one bud or one leaf at a node.

Anisophyllous. Having leaves of a pair that are different in shape and size.

Apex. The tip of a leaf.

Apiculi. Small acute points or tips.

Apiculate. Ending abruptly in a small distinct point.

Arborescent. Resembling a tree in structure, growth, or appearance.

Arched. Curved like a bow.

Auricle. An angular or ear-shaped lobe.

Auriculate. Having angular or ear-shaped lobes.

Axil. The angle between a branch or leaf and the axis from which it arises.

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[1] Definitions are directly from or modified from the following sources: Gary and others (1972), Gove and others (1971), Jackson (1950), Robbins and others (1957), and Usher (1966).

Axis. A plant stem; a straight line with respect to which a structure (as a leaf) is symmetrical.

Base. The point on a leaf that attaches to the stem or petiole; opposite to the *apex*.

Bifid. Divided into two equal lobes by a median cleft.

Bifurcate. To divide into two branches, veins, etc.

Bilobate. Divided into two lobes.

Bipinnate. Twice pinnate.

Bract. A modified leaf from the *axil* of which a cone or spore-bearing structure arises.

Branch whorl. Three or more branches arising from a node.

Brevipedicellate. Pertaining to a short, slender plant stalk that supports a spore-bearing organ.

Bundle. A unit strand of the vascular system of a higher plant, generally consisting of vessels and sieve tubes commonly in association with elongated parenchyma cells and fibers that may surround the strand as a sheath.

Calamitic. Pertaining to the plant genus *Calamites*.

Canaliculate. Grooved or channeled longitudinally.

Carina. A keel-shaped anatomical part, ridge, or process.

Cicatricule. A scar or scarlike mark left on the stem after a leaf or bract has fallen away.

Cicatrix. A scar left on a stem after the fall of a leaf.

Cleft. Referring to a leaf that is divided about halfway to the *midrib*.

Cones. Fruiting structures composed of modified leaves or branches, which bear sporangia.

Confluent. Referring to pinnules that are joined together proximally along the rachis.

Conulate. Shaped like a cone.

Cordaitean. Pertaining to the plant genus *Cordaites*.

Cordate. Heart-shaped, with the point situated at the apex.

Coriaceous. Resembling leather.

Cortex. Primary tissue of a stem or root bounded externally by the epidermis and internally by the phloem.

Cortical. Related to, or pertaining to, the *cortex*.

Costate. Having raised processes such as ribs.

Crenate. Having the margin cut into rounded scallops.

Crenulated. Minutely *crenate*.

Cuneate. Narrowly triangular, with the acute angle toward the base.

Cyclopteroid. Referring to circular pinnules that are attached to the rachis by a single point; in neuropterids, such pinnules are attached along the rachis or at the base of larger tongue-shaped pinnules in much the same manner as stipules on modern plants.

Decorticated. Having the bark or outer covering removed.

Decurrent. Said of parts that extend downward below the point of insertion.

Deflexed. Turned abruptly downward.

Deltoidal. Shaped like a delta; triangular.

Dentate. Having a toothed margin.

Denticulate. Having a finely toothed margin.

Dichotomy. A system of branching in which the main axis forks repeatedly into two branches.

Distal. Far from the point of attachment or origin.

Distant. Widely spaced.

Emarginate. Having the margin notched.

Emergences. Various superficial outgrowths of plant tissue, usually formed from both epidermis and immediately underlying tissue.

Entire. Said of a leaf that has a smooth, continuous margin.

Epidermis. A superficial layer of cells occurring on all parts of the primary plant body.

Falcate. Hooked or curved like a sickle.

Flabellate. Shaped like a fan.

Flexuous. Having turns or windings.

Folial print. A print on shale, siltstone, or other rock that is left after a leaf has fallen away.

Footstalk. The pedicel of a *fructification* or spore-bearing structure.

Fructification. A reproductive organ or fruiting structure of a plant.

Fugaceous. Lasting only a short time.

Furrow. A deep wrinkle or groove in a leaf or stem.

Fusiform. Tapering toward each end.

Granular hair. One of the fine hair-like projections that cover the surface of some leaves.

Heterophyllous. Having leaves of more than one form on the same plant or stem.

Homeomorph. An individual that bears a close resemblance to another organism although the two have different ancestors.

Imbricated. Lapped over each other in regular order.

Imparipinnate. Having one terminal leaflet.

Inferior angle. An angle turned away from the axis of a stem or the rachis of a pinna; for example, the angle that falls between the underside of a leaf and the branchlet from which the leaf arises.

Intercalary. Descriptive of undifferentiated tissue or growth not restricted to the apex of an organ; i.e., growth at nodes.

Internode. The region of a stem between two successive nodes.

Keel. A ridge similar in shape to the keel of a boat.

Lacinia. A deep, irregular, usually pointed lobe.

Laciniate. Cut into deep, irregular, usually pointed lobes.

Lamina (pl. *laminae*). A thin plate or scale; the expanded part of a foliage leaf.

Lanceolate. Shaped like a lance head; tapering to a point at the apex and sometimes at the base.

Lateral angle. An angle between the main vein or rib and a laterally adjacent vein or rib on a leaf or pinna.

Leaf cushion. A swollen leaf base.

Leaf scar. A scar on a twig that results from loss of a leaf.

Ligule. A straplike, membranous structure internal to the leaf base in certain lycopsids, such as *Lepidodendron.*

Ligule pit. A small round print on the cushion surface of a leaf just above the scar; it represents the position of the *ligule.*

"Ligule" scar. A small mark within a leaf scar that records the former site of attachment of the *ligule.*

Lingulate. Shaped like a tongue or strap.

Lobe. A generally curved or rounded subdivision of a leaf or pinnule.

Lunate. Shaped like a crescent.

Lycopod. A fernlike vascular plant characterized by dense, simple, spirally arranged leaves, and by spore-bearing organs situated in the angle formed by the leaf stalk and the stem.

Margin. The peripheral edge of a leaf.

Midrib. The central vein of a leaf.

Midvein. The central vein of a pinna or pinnule that extends directly from the rachis to, or nearly to, the apex.

Mucronate. Ending in an abrupt, sharp terminal point.

Neuropteroid. Referring to pinnules that are attached to the rachis by a single point at their bases.

Node. A slightly enlarged portion of a stem where leaves and buds arise and where branches originate.

Notch. A V-shaped indentation along the margin of a leaf.

Obcordate. Heart-shaped, with the notch situated at the apex.

Obcuneate. Narrowly triangular, with the acute angle at the apex.

Oblanceolate. Inversely *lanceolate*; tapering to a point toward the base.

Oblique. Having the axis not perpendicular to the base.

Obovate. Having an outline similar in shape to the longitudinal section of an egg, with the basal end narrower.

Obtuse. Pertaining to an angle exceeding 90 degrees but less than 180 degrees; also said of a leaf that is rounded at the free end.

Odontopteroid. Referring to pinnules that are attached to the rachis by their entire bases, and by the several veins which pass directly, or after bifurcating one or more times, from the rachis to the margin.

Orbicular. Spherical; circular; rounded.

Orthography. The art of writing words (e.g., plant genera and species names) with the proper letters according to standard usage.

Ovate. Having an outline similar in shape to a longitudinal section of an egg with the basal end broader.

Ovoid. Shaped like an egg.

Ovulate. Referring to a cone, scale, or other structure bearing ovules.

Palmate. Resembling a hand with the fingers spread.

Papilla. A small, nipplelike protuberance.

Parenchyma. A tissue of higher plants consisting of thin-walled living photosynthetic or storage cells that make up much of the substance of leaves and roots, and parts of stems and supporting structures.

Parichnos. A pair of scars located adjacent to the leaf-trace scar of a lepidophytic leaf bolster that reflects the presence of parenchymatous tissue extending into the cortex.

Pecopteroid. Referring to pinnules that are attached to the *rachis* by their entire bases.

Pedicel. A slender plant stalk, especially one that supports a spore-bearing organ.

Pedicellate. Attached by a slender plant stalk.

Penultimate. Next to the last.

Pinna. A primary subdivision of a pinnately compound leaf or frond; a leaflet.

Pinnate. Resembling a feather in having similar parts arranged on opposite sides of an axis.

Pinnatifid. Cleft in a pinnate manner.

Pinnule. A subdivision of a *pinna*, or a secondary subdivision of a pinnately compound leaf or frond; a secondary leaflet.

Pith cast. A fossil formed by the infilling with sediment of the hollow central portion of certain plant stems, particularly of *Calamites* and *Cordaites.*

Plumose. Having a main shaft that bears small filaments; ''feathery.''

Primal. First in importance.

Pteridophyll. A general term referring to ''form-genera'' of Paleozoic ferns and seed-ferns.

Punctation. The condition of having minute pits, dots, or depressions.

Punctiform. Marked by or composed of minute spots or depressions.

Pyriform. Having the form of a pear.

Quadrate. Square, or approximately square.

Rachis. The axis of a large compound leaf; axis of a fern leaf (frond) from which pinnae arise.

Reniform. Kidney-shaped; suggesting a kidney in outline.

Reticulation. Something resembling a net, having veins, fibers, or lines crossing.

Rhizoid. A rootlike structure.

Rhizome. An elongated, underground, horizontal stem.

Rhomboidal. Resembling a rhombus.

Rib. One of the primary veins of a leaf.

Rugose. Full of wrinkles; having the veinlets sunken and the spaces between elevated.

Seat earth. A rootworked bed of rock underlying a coal seam.

Secondary pinna. An individual pinna of a bipinnately compound leaf.

Sessile. Attached directly by the base and not raised upon a stalk.

Setaceous. Set with or consisting of bristles; resembling a bristle.

Shagreen. Having a rough surface covered with small round granulations.

Sigillarian. An arborescent club moss of the genus *Sigillaria* that occurs in Carboniferous deposits; pertaining to *Sigillaria.*

Sinus. A cleft or indentation between adjoining lobes.

Spine. A stiff, pointed plant process, especially one that is a modified leaf or leaf part.

Spatulate. Shaped like a spatula.

Sporophyll. A spore-bearing leaf.

Stigmarian. Pertaining to fossil roots (stigmaria) of plants of the type that lived during the Pennsylvanian Period.

Stoma. A breathing pore or an aperture in the epidermis, surrounded by two guard cells, leading into an intercellular space which communicates with internal tissue.

Stomatal groove. A groove containing a *stoma.*

Striae. Minute grooves or channels.

Striate. Marked with numerous, parallel, minute grooves or channels.

Subacute. Moderately acute.

Subepidermal. Referring to tissue lying beneath or constituting the innermost part of the epidermis.

Submucronate. Nearly *mucronate.*

Subpedicellate. Imperfectly *pedicellate.*

Teeth. Small, sharply pointed marginal projections on a leaf.

Terminal lobe. The last, or most distal, *lobe* on a leaf or pinnule.

Tertiary pinna. An individual pinna of a tripinnately compound leaf.

Trifid. Pertaining to a leaf that has three deep, narrow teeth.

Trifolial. Having three leaves or leaflets.

Truncate. Having the end square or even.

Tubercule. A small knoblike prominence or excrescence on some organs of plants, for example on the rachis of a pinna.

Turbinate. Shaped like a top or inverted cone.

Trizygoid. A leaf arrangement in the node of some sphenophylls in which two pairs of leaves of equal length are situated approximately at right angles to the axis of the stem, and a third, shorter pair of leaves is deflected.

Ultimate. The last.

Uncostate. Unribbed.

Undulate. Having a wavy margin.

Uninerved. One-veined or one-ribbed.

Vascular scar. A mark within a leaf scar left by the breaking away of the vascular tissue from the stem.

Vein. One of the vascular bundles forming the framework of a leaf.

Venation. Arrangement or system of veins in a leaf.

Verticil. A whorl or circular arrangement of similar parts around an axis.

Villous. Having soft hairlike projections.

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